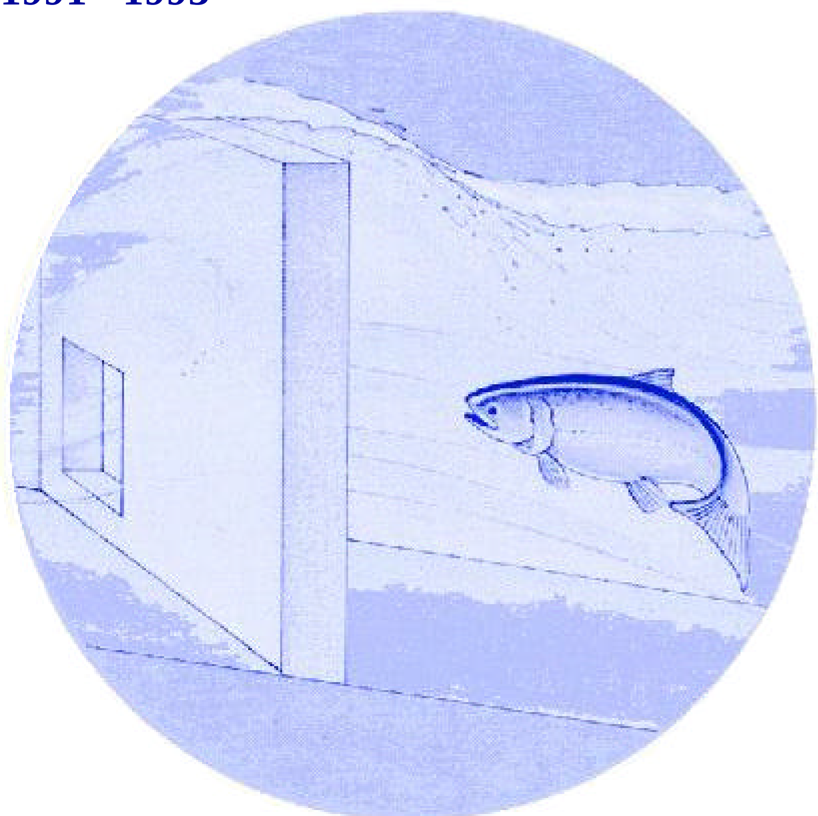
Evaluation of Water Quality Conditions Near Proposed Fish Production Sites Associated with the Yakima Fisheries Project

Final Report
1991 - 1993



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Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

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Evaluation of Water Quality Conditions Near Proposed Fish Production Sites Associated with the Yakima Fisheries Project

FINAL REPORT

Prepared by:

D.D. Dauble
R.P. Mueller
G.A. Martinson

Pacific Northwest Laboratory
Richland, Washington 993 52

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, Oregon 97208-3621

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Executive Summary

In 199 1, the Pacific Northwest Laboratory (PNL) began studying water quality at several sites in the Yakima River Basin for the Bonneville Power Administration. These sites were being proposed as locations for fish culture facilities as part of the Yakima Fisheries Project (YFP). Information on the quality of surface water and groundwater in the basin was needed to develop strategies for meeting artifical and natural production objectives of the YFP.

Our studies indicate that surface water quality parameters near the proposed fish culture facilities are currently suitable for fish production, Water quality conditions in the mainstream Yakima River and its tributaries are generally excellent in the upper part of the watershed (i.e., near Cle Elum), but they are only fair to poor for the river downstream of Union Gap (river mile 107). Water quality of the Naches River near Oak Flats is also suitable for fish production.

Groundwater supplies near the proposed fish production facilities typically have elevated concentrations of metals and dissolved gases. These conditions can be mitigated using best engineering practices such as precipitation and degasification. Additionally, mixing with surface water may improve these conditions. Depending on the location and depth of the well, groundwater temperatures may be warmer than optimum for acclimating and holding juvenile and adult fish. This condition may require that chillers be operated during the late summer holding periods. Additionally, planned water use requirements of some sites (i.e., Oak Flats and Nelson Springs) exceed the capacity of groundwater wells currently drilled at the sites. Thus, additional wells would be required or water requirements for fish culture activities would have to be modified.

Water quality parameters measured in the Yakima River and tributaries sometimes exceed the range of values described as acceptable for culture of salmonids and for the protection of other aquatic life. However, constituent concentrations are within ranges that exist in many northwest fish hatcheries. Additionally, site-specific tests conducted by PNL (i.e., live box exposures and egg incubation studies) indicate that fish can be successfully reared in surface and well water near the proposed facility sites. Thus, there appear to be no constraints to artificial production for the YFP. However, studies by the U.S. Geological Survey and others suggest that water quality and excessive temperature in the lower Yakima River downstream from Prosser may limit natural production of some stocks of salmonids. The principal reasons for decreased water quality in the lower Yakima River include the relatively high volume of irrigation return flow.

A monitoring and evaluation plan should be developed for the YFP that includes water quality measurements of water sources used for fish production and biological measures of fitness. In addition, an integrated temperature monitoring network should be implemented throughout the basin.

Acknowledgments

We are grateful to Lee Harrell, National Marine Fisheries Service, for providing test fish and live boxes, and for coordinating his sample collections with our efforts. Claudia Romsos. Pacific Northwest Laboratory, assisted with field studies and analyzed blood plasma parameters. Joanne Duncan of Pacific Northwest Laboratory compiled the literature synopsis for temperature and flow references. We thank Bob Hager, Hatchery Operations Consultant: Tom Scribner, Yakama Indian Nation; Bill Hopley, Washington Department of Fisheries; and Steve Roberts, Washington Department of Wildlife, for their input on study design and methods. Bob Gatton and Doug Kunkel of CH_2M Hill provided data on facility design, flow, and groundwater characteristics. Ron Costello, Northwest Water Resources, acted as a liaison between Pacific Northwest Laboratory and various technical working groups to define data needs. Dave Fast, Yakama Indian Nation, and Cameron Sharpe, Oregon Cooperative Fishery Research Unit, provided useful review comments. Thomas Clune, Bonneville Power Administration, provided technical direction for our studies, and Jodi Stroklund, Bonneville Power Administration, provided oversight for later stages of research.

Contents

Figures

Tables

1.0 Introduction

In 1987 to 1989, thc U.S. Bureau of Rcclamation (USBR) analyzcd water supplics in the Yakima River (Figurc 1.1) for the Bonncvillc Power Administration (BPA), as required by the Northwest Power Planning Council's (Council) approval of prcdcsign work on the Yakima/Klickitat Fishcrics Project (YKFP) (USBR 1990). Thc Y KFP is a hatchcry supplcmcntalion program planned to rcbuild stocks of anadromous salmonids rcturning to thc Columbia Rivcr Basin. Thc USBR's analysis of thc Yakima Rivcr Basin idcntificd scvcral potential constraints to anadromous fish production, constraints that wcre related to streamflow and watcr quality. The adequacy of watcr supplics in thc Yakima Rivcr Basin for continued natural production was also a significant conccm. Bccausc of thcsc conccms, additional evaluation of water sources for proposed fish production facilitics was rccommcndcd bcforc their final dcsign and construction (Council 1990; USBR 1990). Thc Pacific Northwest Laboratory (PNL) initiated efforts in 1991 to rcsolvc thcsc unccrtaintics as thcy rclatcd to artificial and natural production of supplcmcntcd fish populations. Thc primary objcctivc of our studics was to providc rccommcndations to dcsign engineers for improving water quality conditions at production facilitics proposcd for the Yakima Fisheries Projcct (YFP). An additional objcctivc was to dctcrminc if watcr quality conditions in the Yakima Rivcr Basin were adcquatc to support supplcmcntcd fish populations throughout their entire frcshwatcr life cycle.

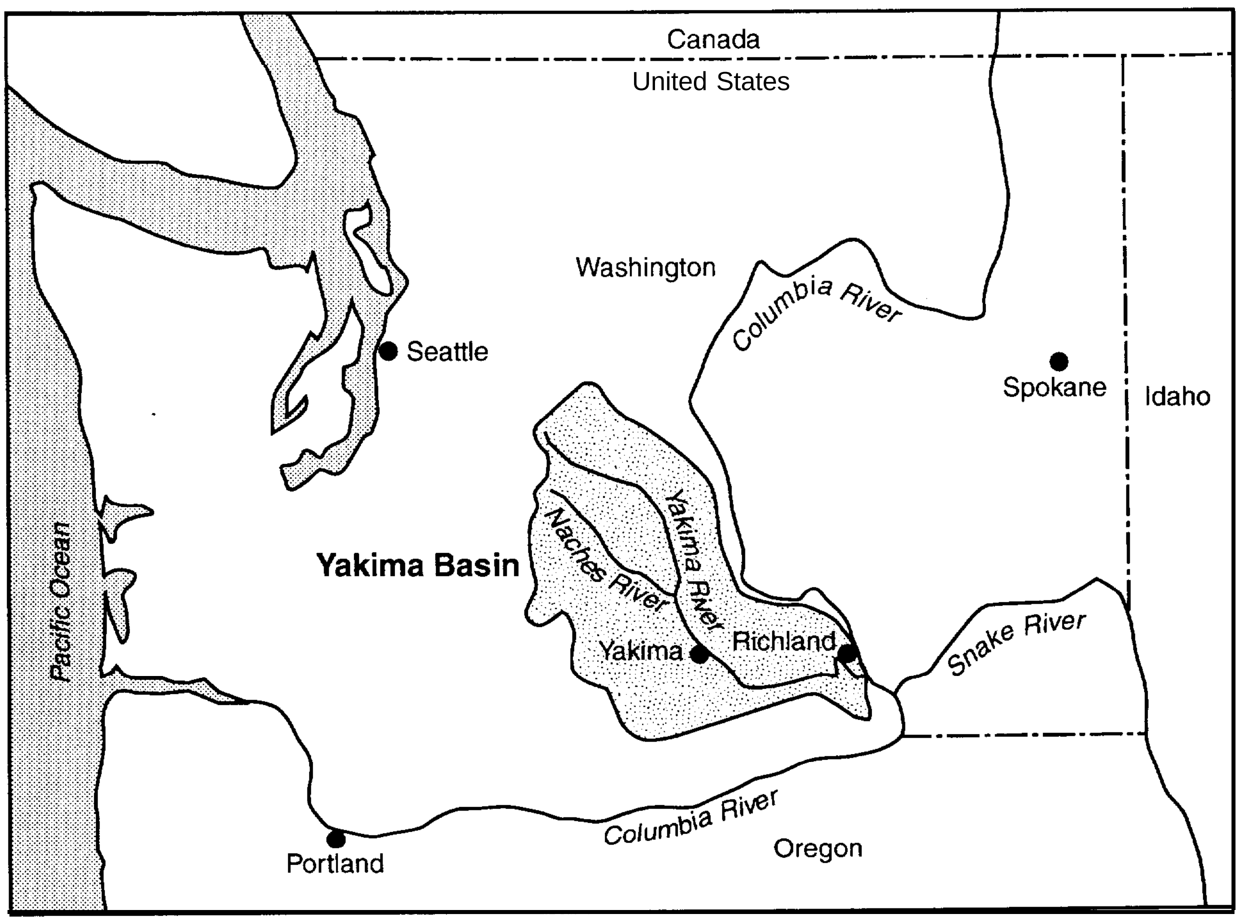

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Figure 1.1, Location of thc Yakima Rivcr Basin

Our initial study results have been used by various technical teams, including those responsible for planning artificial and natural production objectives and those responsible for designing the fish culture facilities. Monitoring activities for the water quality studies were coordinated with fish disease studies conducted by the National Marine Fisheries Service (NMFS) and with net pen rearing studies conducted by the Yakama Indian Nation (YIN). We also coordinated our efforts with water quality studies recently conducted by the U.S. Geological Survey (USGS, Rinella et al. 1992a, 1992b).

Planning and implementation of the YFP have recently changed as a result of National Environmental Policy Act (NEPA) compliance activities. Thus, planned uses of water supplies at some fish production sites may now be different than originally proposed during the predesign phase of the project (BPA 1990). Regardless, the data we gathered provide the framework for future fish enhancement activities planned for the Yakima River Basin. Our studies have already been useful in directing some aspects of engineering design. For example, potential impacts of effluents from the proposed Cle Elum central facility were evaluated during the NEPA process (BPA 1992), and this analysis resulted in recommendations for moving the intake and discharge system to a location with less potential to impact receiving waters.

Studies in 1991 and 1992 focused on evaluating water quality at planned central and satellite facilities and some proposed acclimation sites. Thus, we analyzed all potential surface water and groundwater sources for metals and other potential contaminants. Biological studies included surface water assessments using juvenile rainbow trout and chinook salmon that were held in live boxes at four to six sites and groundwater assessments using rainbow trout eggs. We also developed databases on water temperature and flow for the Yakima River Basin (see Appendix A).

This report is organized into the following six sections. Section 2.0 describes the proposed fish production facilities for the YFP. Section 3.0 discusses methods used for our evaluations. The results of our water quality and biological screening studies are in Sections 4.0 and 5.0, respectively. Section 6.0 is an assessment of the results, and Section 7.0 presents recommendations.

2.0 Proposed Facilities for the Yakima Fisheries Project

Up to five fish production facilities may be constructed for the YFP. An additional 16 acclimation site clusters are also planned in the basin (Figure 2.1; BPA 1992). The proposed locations, general designs, and production plans that relate to water use of these facilities are described below. Additional detail on proposed facilities is provided in BPA (1990, 1992)

2.1 Cle Elum Site

The Cle Elum facility (Figure 2.2) would use both surface water and groundwater to incubate and rear upper Yakima spring chinook salmon (Oncorhvnchus tshawvtscha) and would also provide holding areas for adult spring chinook salmon. In addition, summer steelhead (0. mykiss) may be incubated and reared at this site. Spring chinook salmon eggs would be incubated in the fall and reared from January until March of the following year (i.e., 1 year of rearing). Summer steelhead would be incubated and reared for 15 months at this site (Figure 2.3).

The Yakima River would be the primary source of water to the facility, providing up to 46 cfs during peak operations. Surface water for operations would be pumped from an intake location approximately 1/2 mile upstream of the site. An additional 17.4 cfs of groundwater would be obtained from up to five wells. Two of these wells were drilled at the site in 1989. Well water will be used for incubation and rearing of salmon and steelhead. Hatchery effluent would be discharged through a pipeline to the Yakima River about 500 ft downstream of the site.

2.2 Nelson Springs Site

Initial plans for the Nelson Springs Site (Figure 2.4) included the use of groundwater for incubating salmon and steelhead eggs and surface water for early rearing. Fall chinook salmon would be incubated and reared from October to February, while steelhead would be incubated and reared for 16 months (i.e., January through May of the following year). Recent planning indicates that the site may only be used for early rearing. The availability of warm spring water to accelerate growth of juveniles during rearing was one factor in site selection.

The principal surface water sources for the Nelson Springs facility include Buckskin Creek and Nelson Springs (i.e., Gleed ditch). Water from the Naches River would supplement water supplies during periods of peak use. Groundwater supplies.at the site have not been developed for the YFP. A shallow (50–ft) test well was drilled on the site by CH_2M Hill in March 1992. However, this well yielded only about 50 gpm or <20% of the volume required for planned fish production during the period of maximum use.

2.3 Oak Flats Site

Facilities planned for the Oak Flats Site (Figure 2.5) would use both surface water and groundwater to rear Naches River spring and summer chinook, coho, and Naches summer steelhead. Production plans include incubation of summer steelhead, spring chinook, and coho. Rearing and acclimation would occur during all months in outdoor raceways. The primary water source for the Oak Flats facility would be the Naches River, providing up to 46 cfs during peak water needs. An additional 9 cfs of groundwater would be used from June through March. Effluent wastewater would be discharged back to the Naches River and into the Selah-Naches Irrigation Canal.

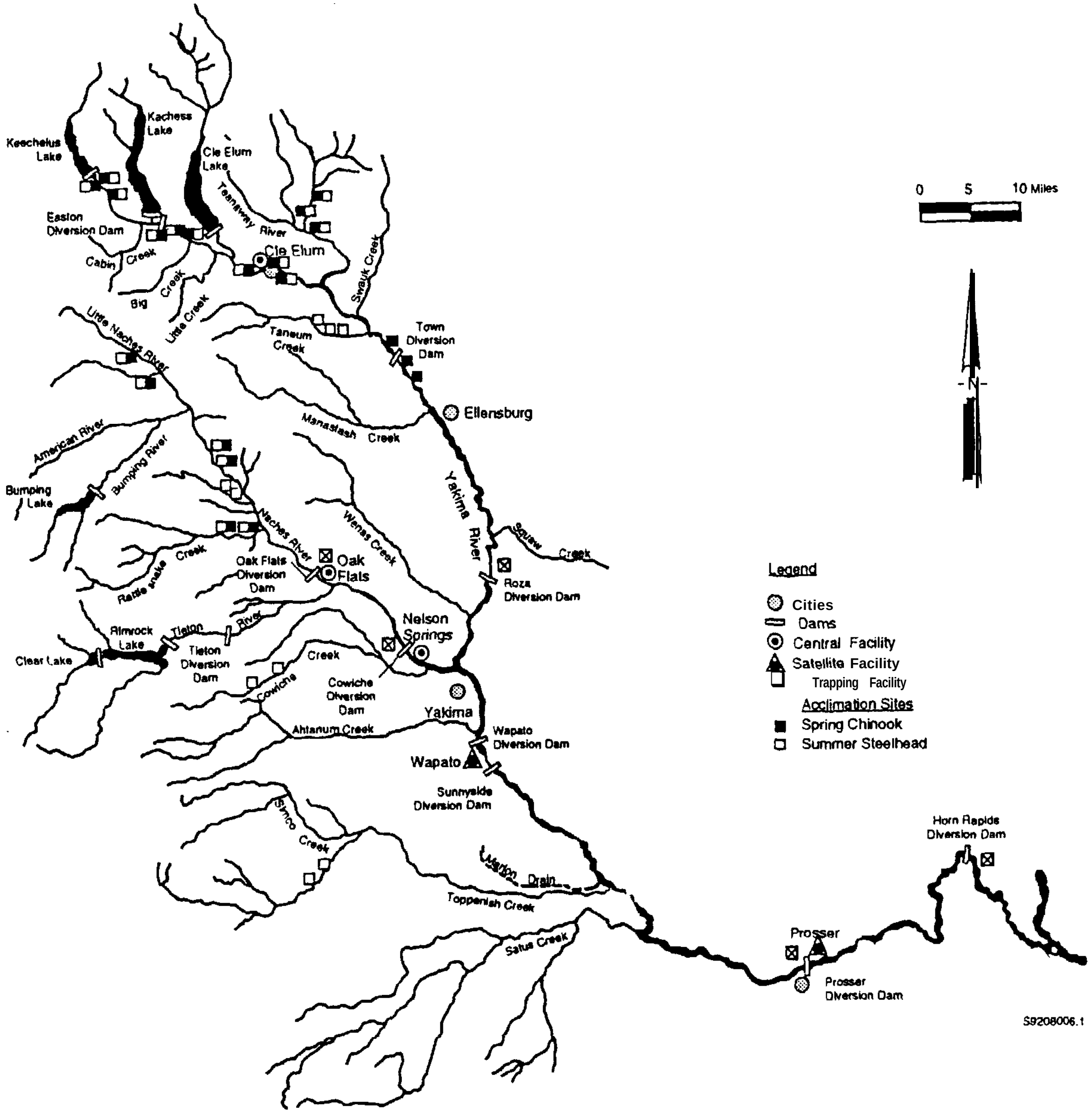


Figure 2.1. Location of Central and Satellite Facilities within the Yakima River Basin

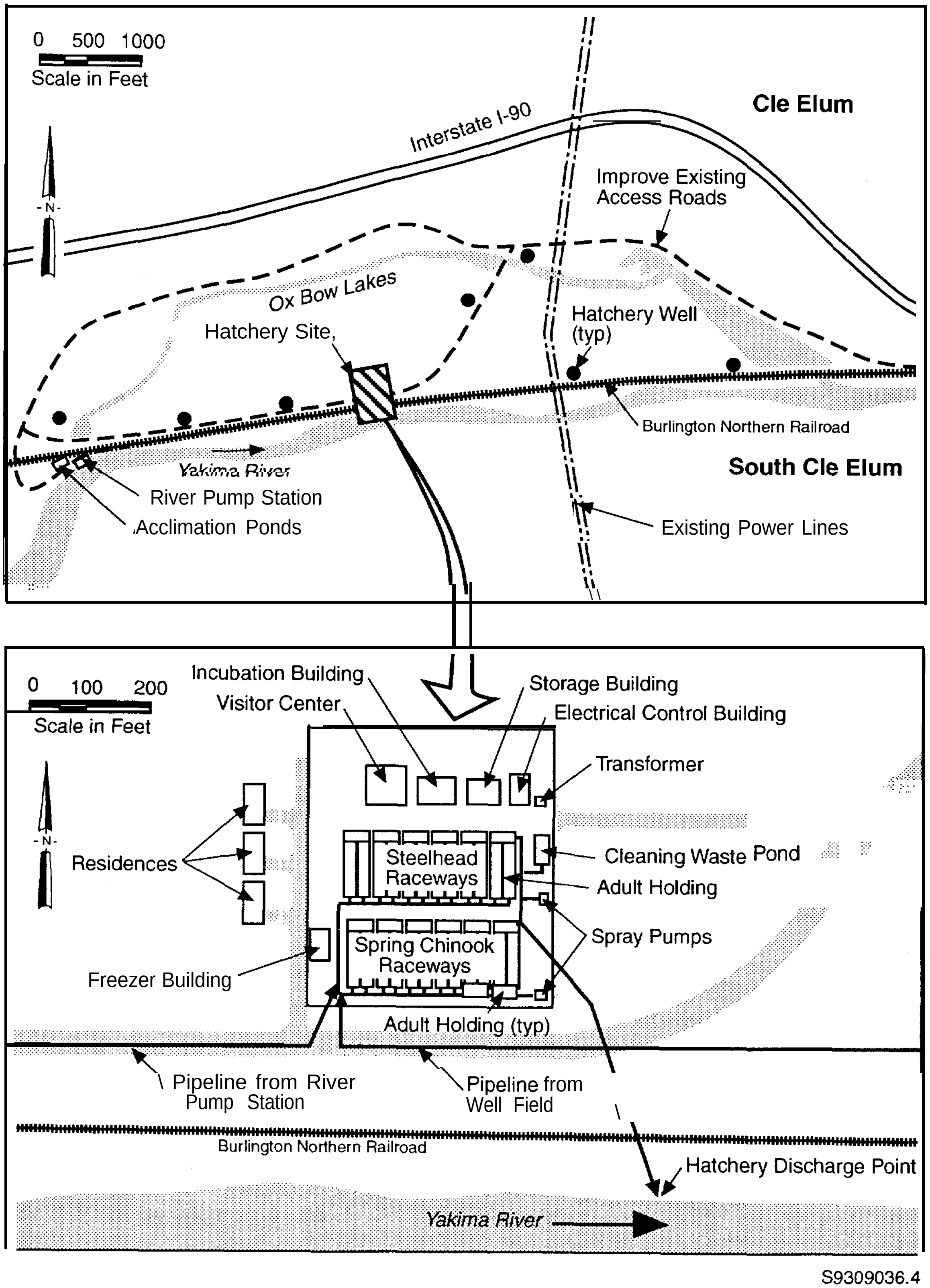


Figure 2.2. Central Facility Design for the Cle Elum Site

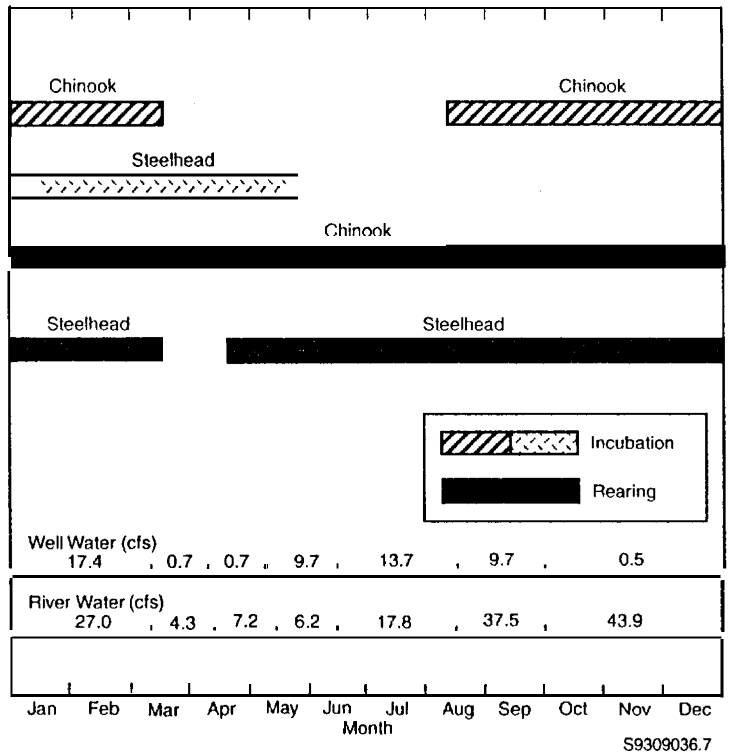


Figure 2.3. Incubation and Rearing Schedule, with Water Requirements. for the Cle Elum Facility

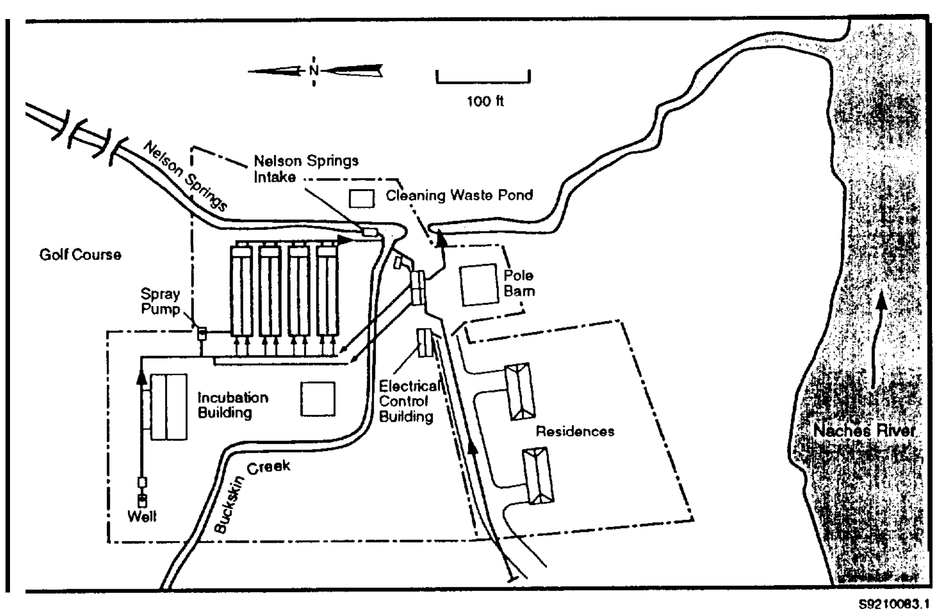


Figure 2.4. Facility Design for the Nelson Springs Site

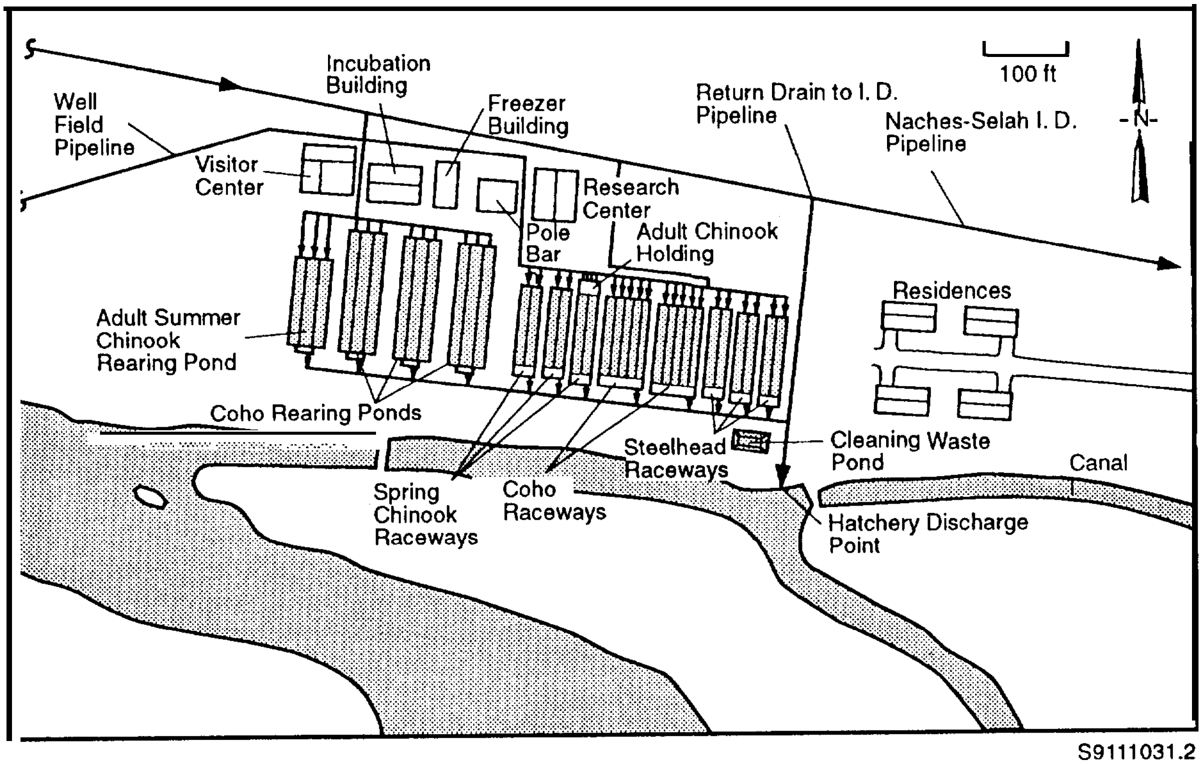


Figure 2.5. Facility Design for the Oak Flats Site

Two wells were drilled at the Oak Flats Site in 1989 by the USBR and one in 1991 by CH_2M Hill. Total output from these wells was estimated to be about 500 gpm. Based on analysis of pumping data, 12 additional 10-in.-diameter wells producing 300 gpm each would be needed to achieve the desired 9 cfs of groundwater.

Surface and well water requirements along with planned fish production schedules are presented in Figure 2.6.

2.4 Wapato Site

The Wapato Site (Figure 2.7) could be used for final rearing and acclimation of coho and fall chinook salmon from March through May. General design includes three coho ponds and 12 raceways for fall chinook. The facility would be located between the existing screening facility and the Union Pacific Railroad. Fish would be released upstream of the screening facility and migrate through the bypass system back to the Yakima River.

The primary surface water source for the Wapato facility would be the Wapato (New Reservation) Canal, which diverts water from the Yakima River near Union Gap. Up to 60 cfs of canal water would be pumped to ponds and raceways from the canal from March through May. Effluent wastewater would be discharged upstream of the screening facility. No groundwater would be required at this site.

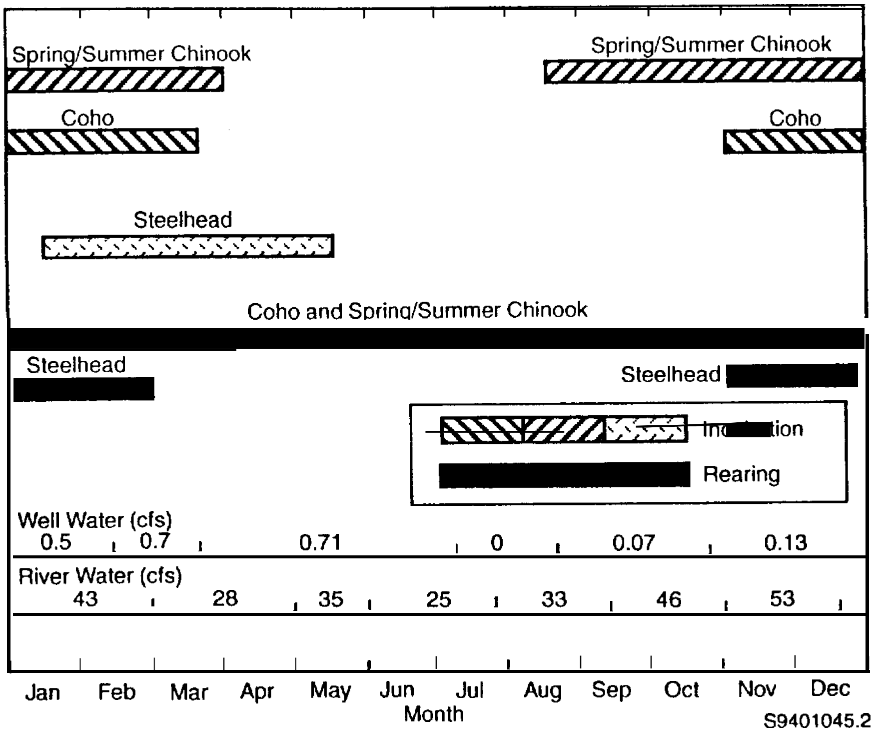


Figure 2.6. Incubation and Rearing Schedule, with Water Requirements, for the Oak Flats Facility

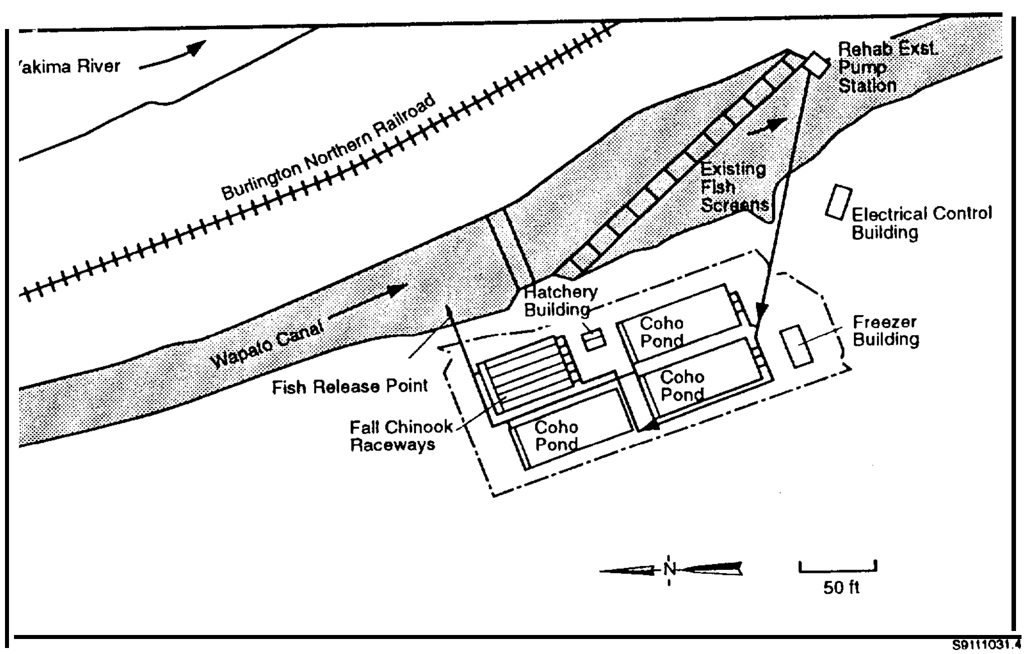


Figure 2.7. Facility Design for the Wapato Site

2.5 Prosser Site

The Prosser facility would be located near the existing juvenile trapping facility (Figure 2.8). Production plans may include incubation, rearing, and acclimation of fall chinook from November to April. In addition, adult fall chinook and coho may be trapped at Prosser Dam, then transported to the facility for broodstock holding and spawning from mid-August to mid-December.

The principal water source for the Prosser facility would include a combination of canal and river water along with groundwater (Figure 2.9). Surface flow requirements include 13 cfs of canal water and 5 to 13 cfs of river water, depending on time of operation. River water would be pumped to the holding ponds, while canal water would be gravity-fed to ponds and raceways. A wastewater pipe would be connected to the existing bypass pipe. Adequate surface flows for operation of the facility are available from the Yakima River. However, up to 6 cfs of groundwater would be required to provide optimum adult holding conditions. Chilled groundwater may be required during the late summer and early fall if adult broodstock are held at the site.

2.6 Acclimation Ponds

Up to 16 acclimation pond clusters with 43 actual sites may be used for outplanting of spring and summer chinook and summer steelhead from the central facilities. An additional 12 acclimation ponds have been proposed for outplanting of fall chinook from lower Yakima River sites. A standardized design of each site includes a pond constructed of earth. lined with river rock, and filled to a volume of 11,000 ft^3. The acclimation ponds would be supplied by surface water from adjacent tributaries and rivers. Water would enter the ponds by gravity-filling or by pumping, at flow rates of 1.2 cfs per pond. The ponds would be filled in the spring when stream flows are usually greatest, and ponds would be drained after the fish are released.

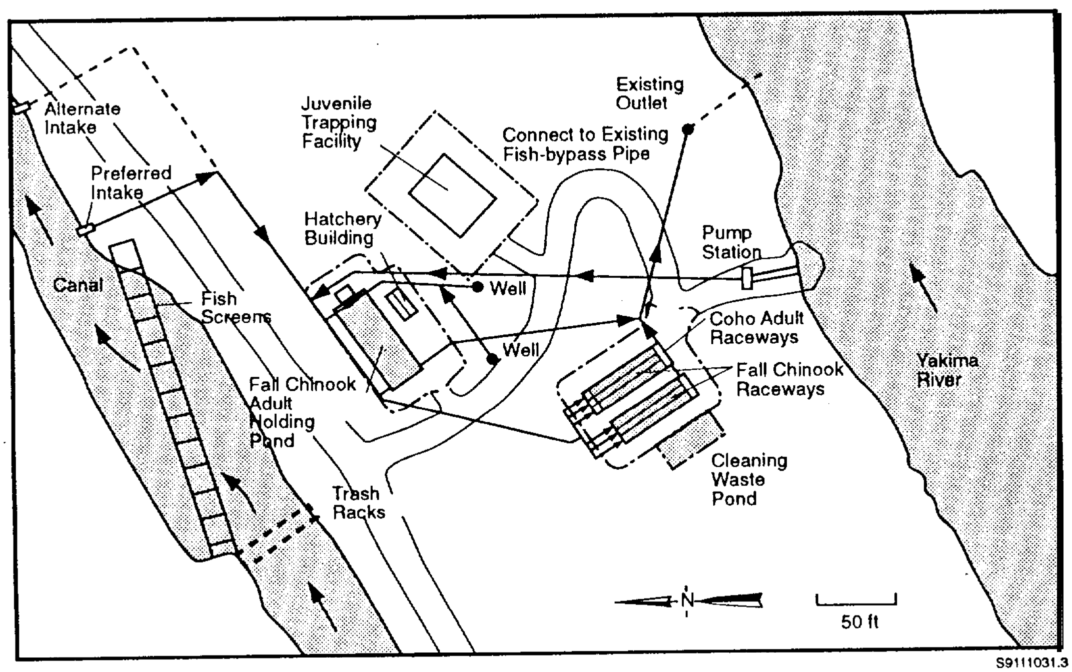


Figure 2.8. Facility Design for the Prosser Site

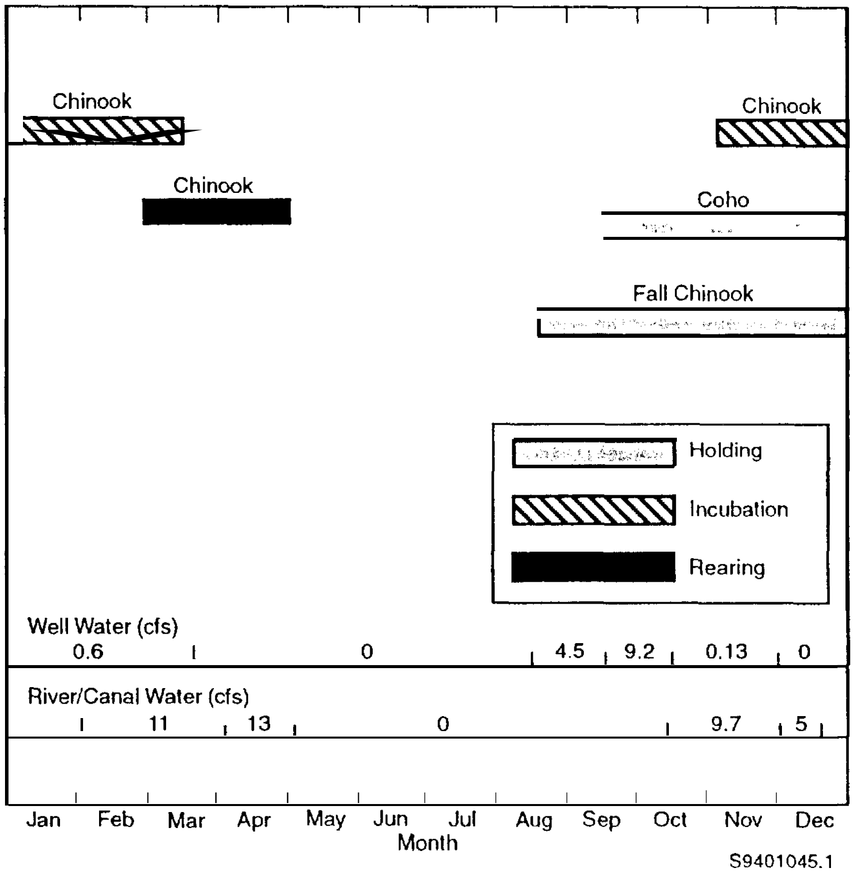


Figure 2.9. Rearing and Holding Schedules, with Water Requirements, for the Prosser Facility

3.0 Study Methods

The objective of our water quality analysis was to characterize constituents of concern and, where possible, to measure their spatial and seasonal variability. Many data were available from the literature. In addition, water samples were collected from selected surface water and groundwater sites for analysis. Some measurements were made in the field (i.e., alkalinity, dissolved oxygen, and temperature) so that effects of collection and storage would not be a factor. However, some samples (i.e., for analysis of metals and organic constituents) were collected, preserved, and fixed in the field, then brought to the laboratory for detailed analysis.

3.1 Water Quality Measurements

Surface water samples were taken from five monitoring sites in 1991 and 1992: 1) the Yakima River near Cle Elum plus the adjacent backwater area (RM 184), 2) the Naches River at the old City of Yakima intake (RM 18), 3) immediately downstream of the confluence of Buckskin Creek and Nelson Springs, 4) just upstream of the fish screens in the Wapato Canal (RM 106), and 5) just upstream of the fish screens in the Chandler Canal (RM 47). In 1992, additional water samples were taken in Toppenish Creek (RM 8 and 34) and in the Yakima River near Horn Rapids Dam (RM 18).

Water sample collection and analysis supported our biological investigations of the proposed fish culture sites. Live boxes containing juvenile salmonids were located near the water quality measurement sites. In addition, groundwater analysis was coupled to laboratory exposures of rainbow trout embryos and fry.

Field procedures for water quality analysis included:

- Water temperature was measured directly using a hand-held thermometer.
- Daily flow was obtained from a hydrograph when available.
- pH was measured directly in the water source using a portable digital pH meter after sample equilibration and calibration with two standard pH buffer solutions (i.e., pH 7 and 10).
- Dissolved oxygen was measured directly in the water using a Yellow Springs Instruments (YSI) oxygen probe. The instrument was calibrated against water-saturated air at ambient temperature before use.
- A Hach field test kit was used to measure hardness and alkalinity.
- Dissolved solids/conductivity were measured using a portable total dissolved solids (TDS) probe after calibration with a known standard.

In addition to taking the field measurements, approximately 100 mL of water was filtered through a 0.45-μM filter and taken to the laboratory for selected analysis of metals and cations. The sample was acidified to 2% nitric acid and saved in a polyethylene bottle, stored at 4°C, and analyzed in the laboratory for metals by the inductively coupled plasma (ICP) or graphite furnace method. Water used for anion and total organic carbon (TOC) analysis was filtered, stored in a glass bottle at 4°C, and analyzed by ICP and a TOC analyzer, respectively. Primary constituents of concern included cations (Al, Cr, Cu, Fe, Mn, and Zn), anions (Br, Cl, F, NO_2, NO_3, and SO_4), and ammonia (NH_3). During 1991, the USGS was subcontracted to analyze water for herbicides and pesticides at Nelson Springs and the Chandler Canal.

A study was initiated to evaluate surface water supplies at the Wapato and Prosser facilities during 1992 because of concerns related to the potential for suspended solids to impact fish-rearing conditions. Sampling dates were chosen to correspond to rearing and holding periods at each site. Water samples were collected in the bypass channels in each facility within mixed water zones. Field measurements taken at the individual sites included temperature, pH, TDS, and turbidity. A Hach model 16800 Portalab Turbidimeter was used to measure turbidity values. Water temperature and dissolved oxygen were measured on a YSI Model 58 portable field meter. Measurements of canal discharge were obtained from the USBR Hydromet database. Both pH and TDS were measured on portable field instruments. Approximately 5 gal of water were collected from each site during the sampling period and kept in a 45°F cooler until laboratory analysis. Total suspended matter and settleable matter were analyzed according to methods described in Rand et al. (1975)

Potential impacts of production facility discharge to receiving waters were analyzed as part of NEPA compliance activities for the YFP (BPA 1992). The analysis considered expected flow volumes and potential nutrient concentrations of both the hatchery effluents and the receiving water. Estimated concentrations of nutrients in the receiving water were then compared with levels known to produce changes in stream ecosystems or to levels promulgated by regulatory agencies. Worst-case scenarios (when effluent concentrations are greatest, usually during periods of lowest river flow) were developed to calculate worst-cast impacts. In our analysis, we compared predicted nutrient levels against the following criteria:

- Maximum nitrate levels should not exceed 0.10 mg/L.
- The upper critical level of phosphate is 0.025 mg/L.

3.2 Biological Screening

Biological screening tests included holding juvenile salmonids in live boxes for extended periods in surface water supplies and exposing early life stages to groundwater from test well drilling sites. In addition, some samples were taken from fish in net pens maintained by the Yakama Indian Nation at the Wapato Canal.

3.2.1 Live Box Studies

Surface water supplies were evaluated *in situ*, using live box enclosures of juvenile salmonids, in 1991 and 1992 at each of the proposed facility sites. All studies were closely coordinated with fish disease studies conducted by Dr. L. Harrell of the NMFS. Approximately 200 presmolt fall chinook salmon were placed in live boxes near proposed fish culture sites and held from April through June 1991. Test sites in 1991 included the Yakima River at Cle Elum, Nelson Springs, Naches River at Oak Flats, Wapato Canal, and Prosser Canal. In May and June 1992, we conducted additional assessments of juvenile rainbow trout held in live boxes at Cle Elum, Nelson Springs, Naches River at Oak Flats, and the Yakima River near Horn Rapids Dam. Fish held at the PNL hatchery served as reference controls during both 1991 and 1992.

Subsamples (n=20) were removed at approximate 2-week intervals to monitor parasites, disease, and general condition. Some fish were transported to the NMFS Manchester Laboratory, where they were examined for gross lesions, obvious ectoparasites, and signs of bacterial or viral infection. Reference specimens were either frozen or fixed in buffered formalin and stored for more detailed analysis.

Mortalities were noted, and length plus weight measurements were made at approximate 2-week intervals by PNL in 1991 and 1992. In 1991, stress or physiological parameters that may have affected survival were measured for all fish at the end of the holding period. Wapato net pen fish were measured three times before their release in 1991. Baseline measurements were made at the Naches Hatchery 2 weeks before placing fish in the live boxes in late May 1992. Fish from all sites except Oak Flats were sampled twice in 1992 for physiological measurements.

For blood sampling, fish were placed in a solution of 100 mg/L MS-222 until they exhibited equilibrium loss. They were then immediately removed from the anesthetic, and blood was taken from the caudal sinus after the tail was removed using a scalpel. Blood was collected into heparinized

50-μL-capacity hematocrit tubes, and the hcmatocrit was mcasurcd visually aftcr centrifugation in an International Equipment Company microcentrifuge for 5 min. Leucocrit values wcrc obtaincd by measuring the buffy coat layer. Plasma was transfcrrcd from the hcmatocrit tubcs to serum vials, pooling up to 5 fish to obtain a minimum of 75 μL for each samplc. Plasma samples were storcd at 4°C and brought back to the laboratory for analysis. A flame photometer was uscd to measure sodium and potassium (50 μL of plasma required), with thc rcmaining volume analyzed for glucose, total protein, chloride, calcium, and cholesterol using a Cobas Fara instrumcnt.

3.2.2 Incubation Bioassays

Toxicity tcsts with early life stages havc bccn recommcndcd for obtaining data to cstablish water quality criteria because thc embryo-larval and juvenile stagcs arc usually the most sensitive life stages to organic and inorganic chcmicals (McKim 1977). We conducted screening bioassays with sensitive life stagcs (i.e., embryo-larval) of salmonids in 1992 using groundwater sources planned for fish culture. Water quality paramctcrs that WC mcasurcd wcrc similar to thosc mcasurcd for surface watcr supplies (Table 3.1)

Static cxposurcs were uscd to test the suitability of groundwatcr from Prosscr, Nelson Springs, Oak Flats, and Clc Elum for hatching rainbow trout cggs. PNL hatchcry wcll water was uscd as the control. Water was samplcd from the four sitcs after the wclls wcrc purgcd thrcc times. Anions wcrc analyzed with a Dionex AI450 chromatographic system; cations with an ICP-Absorption Emission Spcctroscopy; and TOC with a DC-80. Othcr paramctcrs wcrc mcasurcd according to methods prcviously dcscribcd for surface watcr samples.

Ten 38-L-capacity aquariums wcrc uscd, each containing two egg tubes constructcd from PVC pipe. Fiberglass scrccning was glucd to thc bottom of cach tube to support fcrtilizcd and water-hardcncd rainbow trout cggs. A filtcrcd air source circulatcd watcr through thc glass tubing and provided acratcd water to eggs in thc tubes. Additional aeration was supplicd to each aquarium to prcvcnt tcmpcrature stratification. Air prcssurc and water flow wcrc adjustcd to prcvcnt shocking eggs during scnsitivc stages of dcvelopmcnt. Aquariums wcrc placcd insidc a watcrbath supplied with a flow-through watcr source. Temperature was monitorcd continuously in thc aquariums with a thermograph and maintained at 10°C.

Ten aquariums wcrc used for cxposurcs (n = 2 for cach watcr source including thc PNL wcll watcr control). Aquariums wcrc fillcd with 25 L of watcr and randomly positioned in the watcrbath (Figurc 3.1). Water was cxchangcd in thc aquariums oncc thc cggs wcrc cycd (i.e., at 2 wccks) and wcckly thcrcaftcr. Water uscd for cxchangcs was storcd at 10°C. A Hcath incubator tray was also modificd to hold two cxpcrimcntal cgg lots. Two scctions of PVC pipc wcrc attachcd to thc Hcath incubator tray to simulatc conditions in thc cgg tubcs including cgg dcnsity. The Hcath incubator was supplied with flow-through PNL hatchcry wcll watcr at 10°C and scrvcd as a rcfcrcncc control to the static bioassay technique.

Two mature fcmalc rainbow trout and four mature malc rainbow trout wcrc used for thc cxperimcnt. One fcmalc was fcrtilizcd with milt from two malcs. Fcrtilizcd cggs wcrc water-hardcncd in

Table 3.1. Paramctcrs Mcasurcd in Groundwatcr during Egg Incubation Tcsts

Anions	Cations	Other
Br	Al	Alkalinity
cl	Cr	Dissolvcd oxygen
F	cu	Hardness
NO_2	FC	PH
NO3	Mn	Tcmpcrature
Oxalate	zn	
PO_4		
SO_4		

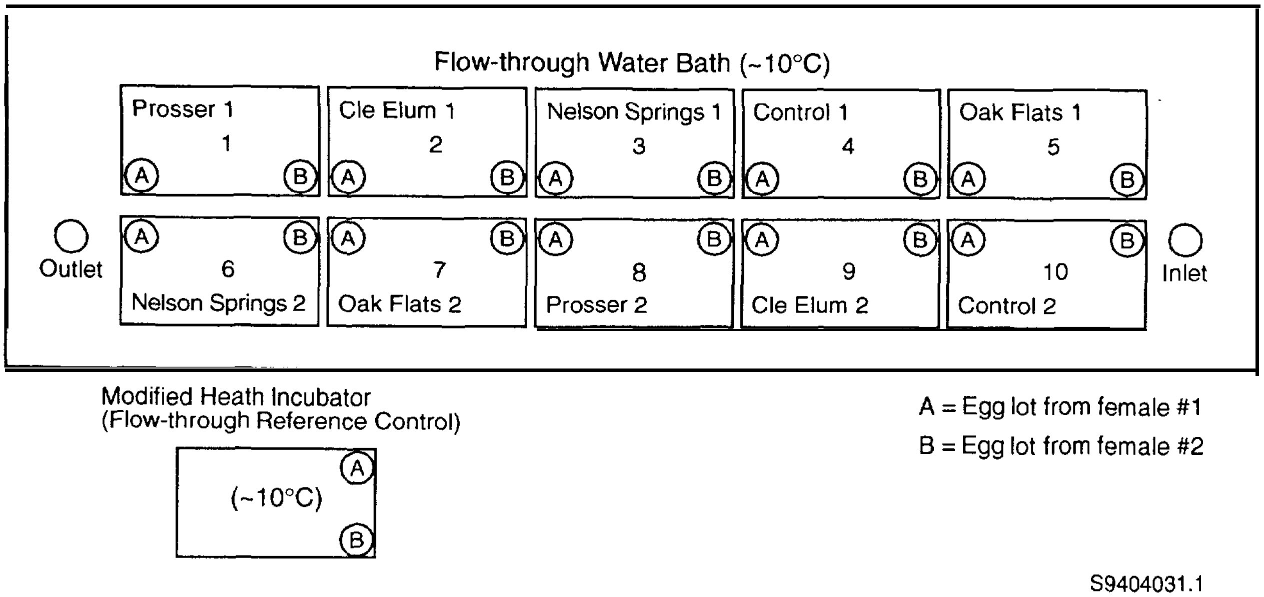


Figure 3.1. Experimental Design for the Egg Incubation Exposures using Groundwater from Four Sites and the Pacific Northwest Laboratory Hatchery Source

beakers containing the same water sources used for the egg incubation bioassay tests. Blank eggs were picked and counted within 24 hours after fertilizing. After the initial removal of dead eggs, the remaining eggs from the two females were split into 22 groups. A minimum of 80 rainbow trout eggs was used in each egg tube. Egg tubes were labeled to keep track of the separate lots. The remaining eggs were left undisturbed until they reached the eyed stage of development. Egg incubation took place in the dark and exposures continued 2 to 3 weeks after hatching.

Eggs were monitored for fungus and disease during the test, and infected eggs were counted and removed. The following attributes and endpoints were monitored:

- the quantity of eggs and number of eggs picked from each egg tube
- observations of egg health
- duration of time to reach the eyed stage of development
- incubation and hatching duration
- post-hatch mortalities
- percentage of normal and abnormal larvae
- number and description of alevin malformitics
- alevin health
- alevin mortalities
- number of fry after 3 weeks post-hatch

- percentage of normal and abnormal fry
- weights and lengths of fry at the termination of the egg incubation bioassay test.

3.2.3 48-Hour Static Bioassays

Groundwater was collected from the Oak Flats and Prosser well sites during test drilling operations for 48-hour static bioassay tests with juvenile rainbow trout. Well water from PNL was used as a control. Water samples were taken from the different groundwater sources and analyzed for key constituents using methods described for the egg incubation exposures.

Two separate static bioassays were conducted; one with groundwater from an Oak Flats well and the other from groundwater taken from the Prosser site. The control in each exposure was well water from the PNL hatchery. Aquariums (n = 2) were placed in a water bath at 12°C with thermographs to continuously monitor water temperatures. Aquariums were aerated to keep dissolved oxygen levels between 7 and 8 mg/L. Ten rainbow trout fingerlings were placed in each aquarium for the 48-hour test period and survival noted.

4.0 Water Quality and Flow Characteristics

Our analysis includcd a summary of rclcvant surface watcr quality characteristics reported by other agencies that have conducted studics in the Yakima Rivcr Basin, including thc USBR (1990); data rctrievcd from EPA's STORET database covcring the intcrval from 1974 to 1987; historical values reported by the USGS (Rinclla et al. 1992a); and data from dctailed water quality investigations taken by the USGS during 1987 to 1991 (Rinclla et al. 1992b). Wc also report additional water quality data from surface water and groundwater invcstigations conductcd by PNL and CH_2M Hill in 1991 and 1992.

Surface water supplies arc typically used for rcaring and acclimation of juvcnilc salmonids. Well water is planned for most adult holding, incubation, and hatching, because it is pathogen-free and typically provides morc uniform tcmpcraturc conditions than surface watcr sources.

4.1 Cle Elum Site

Water sourccs for thc Clc Elum Sitc includc surfacc watcr from thc Yakima Rivcr and groundwater from an underlying aquifer.

4.1.1 Surface Water Characteristics

Data on thc charactcristics of surfacc watcr quality wcrc gathcrcd by the USBR from 1974 to 1987 and in 1989 at Clc Elum (Tablc 4.1). None of the water quality paramctcrs analyzed appeared high, and

Table 4.1. Historical Surface Watcr Quality Mcasurcd from the Yakima River ncar Cle Elum bv thc U.S. Bureau of Rcclamation. Samplc sizc = 1 unlcss othcrwisc notcd. All values are mg/L.

Parameter	12/1 9/89	1974 to 1987	Samolc Size
Al	0.04	0.006	
Ca	0.002	nd[(a)]	
cl	0.1	nd	
Cr	0.002	0.002	
Cu	0.002	0.0024	
F	0.1	nd	
Fe	0.09	0.135	
K	0.391	1.17	
Mn	0.005	0.01	
Mg	2.31	0.0024	
Na	2.3	4.6	
NH_3	0.002	0.0001	135
NO_2	--[(b)]	nd	
NO_3	0.082	0096	57
PH	8.47	7.45	10
SO_4	1.44	0.96	
zn	0.005	0.0035	
Alkalinity	21	nd	
Hardncss	34	nd	
TDS	44	nd	

(a) nd = nonc dctectcd.
(b) -- = not mcasurcd.

only aluminum and zinc cxcecdcd Alaska Dcpartmcnt of Fish and Gamc (ADFG) aquaculture critcria (USBR 1990). These valucs appcar to rcflcct thc natural background conccntrations of this part of the Yakima River Basin.

Thc USGS conductcd extensive water quality analysis of thc surface watcr at Clc Elum from 1987 to 1991 (Rinella et al. 1992b). The rcsults of thcir metals analysis arc summarized in Tablc 4.2. Most parameters analyzed wcrc at slightly lowcr concentrations than those rcportcd by thc USBR. Additional investigations by PNL. in 1991 indicatcd similar valucs (Tablc 4.3). In gcncral, constitucnt concentrations in the backwater area were similar to thosc found in thc Y akima Rivcr.

Avcragc flows for thc Yakima River at Cle Elum have rangcd from a low of about 500 cfs in Novembcr, to over 3000 cfs in July (1926 to 1987 watcr ycars, USBR 1990; Figurcs 4. I and 4.2). The lowest flows have ranged from 300 to 350 cfs during October and Novcmber of dry ycars (USBR 1990).

Table 4.2. Mctals Analysis of thc Yakima River at Cle Elum by thc U.S. Gcological Survey, April 1987 to Fcbruary 1991

Paramctcr	Conccntration, m g/L	n
Cd	<0.001 - 0.001	14
Cr	<0.001 - 0.005	8
Cu	<0.001 - 0.003	15
Fc	0.010 - 0.044	6
Hg	<0.0002 - 0.001	11
Mn	0.002 - 0.007	5
Ni	<0.100	5
Pb	<0.001	12
zn	0.004 - 0.019	6

Table 4.3. Surface Watcr Quality Characteristics for thc Mainstream Yakima Rivcr and Adjaccnt Backwatcr Arca near Clc Elum. Values as mg/L rcprescnt the range found for April to June 1991 (n=3).

Paramctcr	Yakima Rivcr	Backwatcr Pond
Al	<0.0071 - 0.0215	<0.0071 - 0.0163
Alkalinity	23 - 37	40-46
cl	nd[(a)] - 0.76	nd - 3.6
Cr	<0.0025 - <0.0027	<0.0024 - <0.0027
cu	<0.0012 - <0.0016	<0.0013 - <0.0016
F	nd - 0.08	nd - <0.030
Fc	0.008 - 0.02 16	0.019 - 0.034
Hardncss	22 - 84	45 - 68
K	nd - <0.12[(a)]	nd - <0.12
Mn	0.001 - 0.003	0.006 - 0.007
NH_3	nd - <0.007	nd - <0.007
NO_2	nd - <0.08	<0.02 - <0.08
NO_3	0.020 - 0.220	0.012 - 0.530
Oxalatc	nd - <0.12	nd - <0.12
pH	8.1 - 9.3	7.7 - 8.6
SO_4	nd - 1.28	nd - 2.18
TDS	20 - 30	50 - 60
Zn	<0.0009 - 0.0070	<0.0008 - 0.0016

(a) nd = nonc dctcctcd.

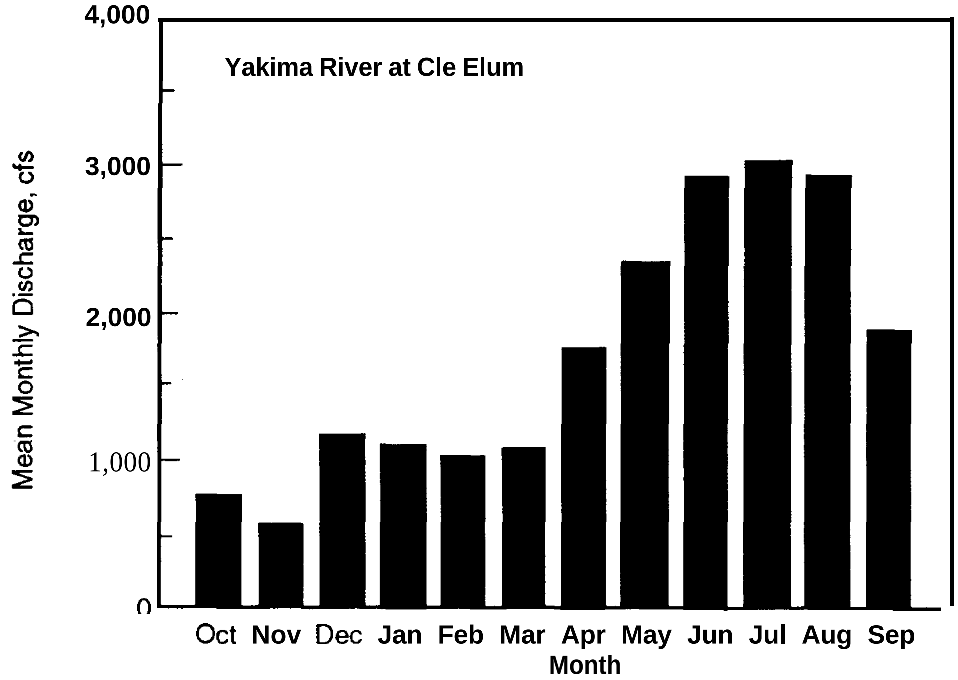
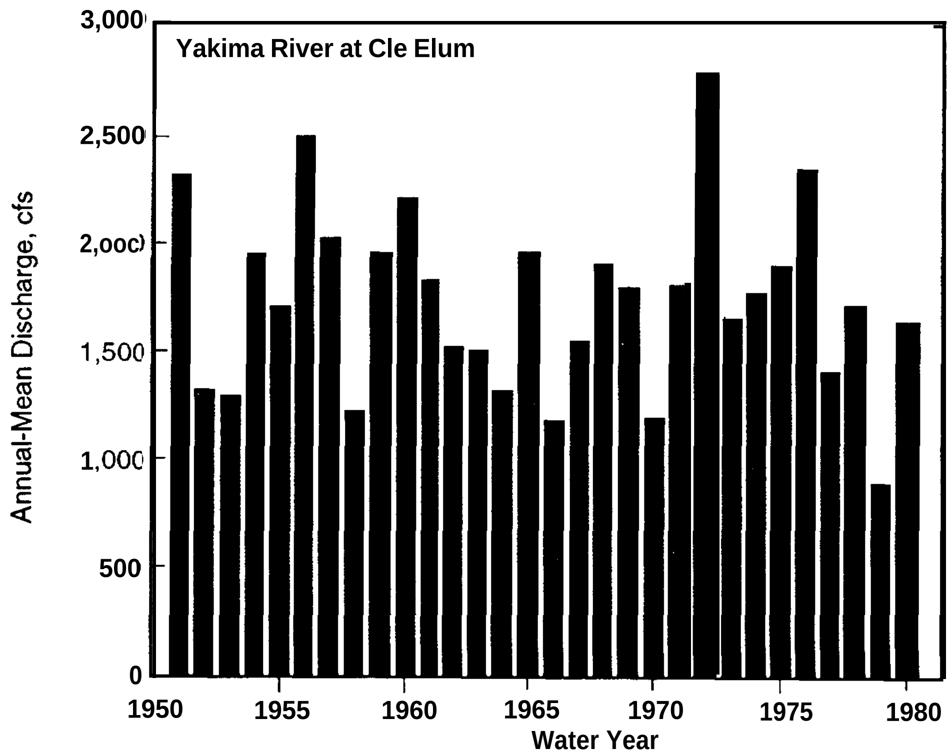


Figure 4.1. Mean Monthly Discharge Rates for the Yakima River at Cle Elum, 1926 to 1987 (from USBR 1990)



59309036.6

Figure 4.2. Annual Mean Discharge Rates at Cle Elum from 1950 to 1980

Thus, the hatchcry rcquircmcnt of up to 44 cfs during peak dcmand in March could result in withdrawals of up to 1.5% to 8.8% of thc availablc rivcr flows. Hatchcry opcrations during the rest of the year would result in lower withdrawals. All operations arc planncd to bc nonconsumptivc (i.c., thcrc will be no net loss of water to the Yakima Rivcr), cxccpt bctwccn thc point of withdrawal and thc discharge location. Thus, flows downstrcam of thc hatchery dischargc would not be rcduccd during opcration of thc facilities.

Maximum water tcmpcraturcs in thc Yakima Rivcr at Clc Elum during 1974 to 1987 rcached 64°F (USBR 1990). The avcrage watcr tcmpcraturc of thc Yakima Rivcr at Clc Elum during 1987 to 1991 ranged from 35°F in January to 62°F in August (Rinclla ct al. 1992b). Average watcr tcmpcraturcs during August and early Scptcmbcr cxcccd the 58°F limit that is rccommcndcd for rearing juvcnilc salmonids (Figure 4.3). Groundwatcr will bc used to providc tcmpcralurc control during this pcriod.

4.1.2 Groundwater Characteristics

Groundwatcr charactcristics from both wclls at thc Clc Elum Site arc summarizcd in Tablc 4.4. Water quality tcsting of thc wcll drillcd in 1989 by thc USBR indicatcd that magncsium, aluminum, sodium (too low), carbon dioxide, and manganesc did not mcct ADFG aquaculture critcria (USBR 1990). The same wcll was tcstcd by CH_2M Hill on Dcccmbcr 12, 1989, and similar rcsults wcrc obscrvcd. PNL analyzcd watcr from thc wcll during 1992 whilc conducting incubation tcsts with rainbow trout eggs. Paramctcrs that cxcccdcd ADFG aquaculturc critcria includcd manganesc, magncsium, aluminum, and chloride. Howcvcr, nonc of thc conccntrations wcrc considcrcd dctrimcntal for fish culturc bccausc thcy eithcr mct or wcrc bclow othcr aquaculturc critcria whcn hardncss is considcrcd. In addition, any mixing of the surfacc water and wcll watcr would furthcr cnhancc watcr quality. As of this time, no water quality testing was conductcd from the tcst wcll drillcd by CH_2M Hill in 1991.

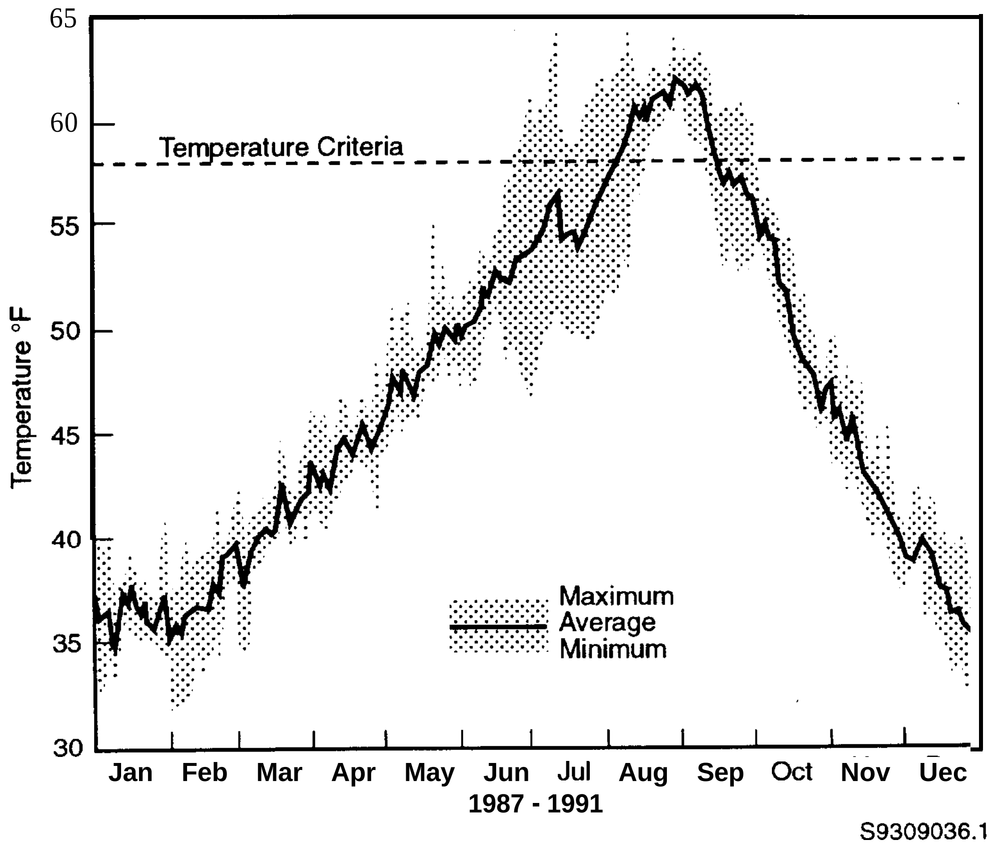


Figure 4.3. Avcragc Monthly Walcr Tempcraturc Profilcs in Rclation to Optimum Rcaring Tcmpcraturc Criteria (58°F) al Clc Elum

Table 4.4. Major Wcll Watcr Quality Paramctcrs Mcasurcd at Clc Elum by Pacific Northwest Laboratory (n=5) and U.S. Burcau of Reclamation, (n=1) Wcll Numbcr CE-PW-2. Valucs as mg/L.

Parameter	PNL, Novcmbcr 1992 to April 1992	USBR, Dcccmbcr 19. 1989
Al	0.032 - 0.043	0.020
Ca	28.8 - 29.9	--
Cl	0.00 - 7.55	0.10
Cr	0.003 - 0.005	0.002
Cu	<0.0018 - <0.0020	0.003
F	0.00-0.11	0.100
Fc	0.011 - 0.026	0.100
K	0.57 - 0.68	0.782
Mg	14.71 - 15.78	15.320
Mn	0.046 - 0.052	0.035
Na	5.26 - 5.87	0.004
NH_3	--(a)	0.002
NO_3	0.00 - 0.53	0.02
NO_2	0.00 - 0.27	--
Oxalatc	0.00 - 9.5 1	
pH	7.9 - 8.4	8.15
SO_4	10.3 - 11.9	11.53
TDS	180	162
zn	<0.0013 - 0.039	0.005
Alkalinity	135 - 143	129
Hardness ($CaCO_3$)	144 - 160	141
Dissolvcd oxygen	--	0.7
Tcmpcraturc (°F)	46 - 50	47

(a) -- = not mcasurcd.

One observation and two production wclls wcrc drillcd ncar thc northcrn edge of thc site by the USBR in 1989. Onc production well was drillcd to bcdrock at a dcpth of 107 ft bclow ground surface and thcn abandoned. Preliminary pumping of thc othcr wcll found that thc aquifcr could yicld up to 1.5 cfs for a sustaincd pcriod. In 1991, CH_2M Hill drillcd tcst and production wclls bascd on seismic studics and data acquired from thc USBR. A wcll was drillcd about 700 ft southwcst of the cxisting USBR production wcll to a final dcpth of 213 ft. This wcll bccamc artisan from 113 to 189 ft bclow ground surface. Pumping tcsts pcrformcd at thc wcll indicatcd a maximum sustaincd yicld of 3.3 cfs. It was also dctcrmincd by CH_2M Hill that this aquifcr is isolatcd from thc Yakima River by a clay laycr and thcrc is minimal leakage (recharge) at thc sitc from thc rivcr to thc aquifcr. Bascd on thcir studics, CH_2M Hill rccommcndcd that four additional 16-in.-diamctcr wclls bc drillcd along thc Burlington Northern Railroad. Thcsc wclls, along with thc two existing wclls, would mcct thc groundwatcr rcquircmcnts at thc site.

Watcr tcmpcraturc of thc USBR production wcll at Clc Elum was 46.2°F in Dcccmbcr 1989. Groundwatcr tcmpcraturc was also monitorcd by CH_2M Hill from mid-Junc 1991 through August 1992. Thcsc studics rcportcd a nearly constant watcr tcmpcraturc of 48°F and indicatcd that thcrc was little influcncc of rivcr infiltration to groundwatcr. Critcria for thc incubation and rcaring of salmonids is 38°F to 55°F and 33°F to 58°F, rcspcctfully. Rccommcndcd tcmpcraturcs for holding prcspawning salmon should bc 55°F or lcss. Thus, groundwatcr tcmpcraturcs arc adcquatc such that chillcrs arc not csscntial for cgg incubation activitics at this sitc. Howcvcr, tcchnical tcams havc rccommcndcd that chillcrs be used to manage thc rate of cgg dcvclopmcnt during incubation. Thus, a mixturc of groundwatcr and surface watcr would be nccdcd during thc adult spring chinook holding pcriod of May to Scptcmber.

4.1.3 Hatchery Effluent

Estimates of potential nutrient input to the Yakima River from operations at the Cle Elum Site considered both the monthly average low flow and the lowest monthly mean flow (Table 4.5). The only time that excessive nutrients could be present (nitrogen = 0.33 mg/L) would be at the monthly average low flow for October (82.5 cfs) and November (94.2 cfs). Mean monthly flows during all other months of the year ranged from 132 to 1254 cfs and indicated that if the "worst-case" nutrient concentrations were achieved, any problems would be short-lived. Further, the low flow conditions occur during the winter months when temperature and light conditions are lowest. Thus, any potential for excessive algae growth from the higher nutrient regime would be ameliorated by limnological conditions or dilution.

4.2 Nelson Springs Site

Water sources for the Nelson Springs Site could include surface water from Nelson Springs, Buckskin Creek, and/or the Naches River, and well water from nearby aquifers. General water characteristics were determined for each potential source.

4.2.1 Surface Water Characteristics

Water quality samples were collected from Buckskin Creek and Nelson Springs in August 1988 and April 1989 by the USBR (1990). Water quality parameters that did not meet ADFG aquaculture criteria included aluminum, chloride, and nitrate. In addition, low levels of dissolved oxygen and high levels of carbon dioxide, hydrogen sulfide, and nitrogen gas were observed.

PNL collected additional water samples during the spring of 1991 from Nelson Springs. All concentrations were below aquaculture standards with the exception of aluminum and nitrate (Table 4.6). Results of a 1991 metals analysis of surface water are presented in Table 4.7 and also indicated that elevated levels of aluminum and zinc were sometimes present.

The USGS collected three sets of water samples from Nelson Springs and Buckskin Creek in the spring of 1991 to determine if there were measurable quantities of herbicides and pesticides in these drdinages. The USGS analysis indicated no detectable concentrations of herbicides and pesticides during this interval. Additional details on constituents measured and detection limits are included in Appendix B.

Combined flows from Buckskin Creek and Nelson Springs ranged from 9 cfs in March to 26 cfs in September 1989 (USBR 1990). The relatively wide fluctuation in flow from the springs was believed to be caused by groundwater return flow from nearby irrigated lands. Estimated combined flows (during 1979 to 1981 and in 1990) ranged from 9.5 to 26 cfs based on unpublished data obtained from stream gauge records (see Appendix B, Table B.7). Flows in the Naches River downstream of Nelson Springs

Table 4.5. Predicted Nutrient Inputs from the Proposed Fish Production Facility at Cle Elum. Concentrations are in mg/L and were based on a low flow of 82.5 cfs and mean flow of768 cfs.

	Low Flow	Mean Flow
Percent effluent	36	6
Effluent nitrogen	0.88	0.04
Effluent phosphorus	0.04	0.02
Receiving nitrogen	0.02	0.01
Resultant nitrogen	-0.033 [a]	0.07[a]
Resultant phosphorus	0.021	0.012

(a) Occasionally exceeds recommended limits in receiving waters.

Table 4.6. Surfacc Water Characteristics for Nclson Springs (NS) and Buckskin Creek (BC) from April to May 1991. All values are mg/L.

Parametcr	NS/BC Confluencc, April-May 1991 (n=5)	Nelson Springs, April -May 1991 (n=5)	Buckskin Creek, May 1991 (n=2)
Al	0.035- 0.044	0.054 - 0.056	0.028 - 0.035
Cl	5.45 - 5.50	nd	nd
Cr	<0.0023 - <0.0027	<0.0025 - <0.0027	<0.0025 - <0.0027
cu	<0.0012 - <0.0016	<0.0015 - 0.0024	<0.0015 -0.0016
F	0.11 - 0.15	0.24	0.13
Fe	0.025 - 0.039	0.016 - 0.038	0.027 - 0.049
Mn	0.002 - 0.004	0.003 - 0.005	0.003 - 0.004
NH_3	<0.007 - 0.024	nd	nd
NO_3	1.44 - 6.86	6.20	5.34
PH	7.7 - 8.28	8.69	8.52
PO_4	nd - 0.37[a]	0.4	nd
SO_4	10.80 - 12.22	14.72	10.36
TDS	120 - 160	140	110
zn	0.002 - 0.037	<0.001 - 0.018	0.002 - 0.040
Alkalinity	95 - 145	135.6	79.9
Hardness	89.9 - 135	134.2	81.4
Diss. Oxygcn	10.35 - 12	10.3	10.3

(a) nd = none dctectcd.

Table 4.7. Metals Analysis of Nclson Springs (NS), Buckskin Crcek (BC), and thc Confluence by the U.S. Gcological Survcy during 1991. All valucs are mg/L.

Paramctcr	Nclson Springs (n=3)	Buckskin Crcek (n=2)	NS/BC Confluence (n=2)
Al			
Cr	0.038 - 0.054	0.027: 0.033	0.034 - 0.043
	co.002 - <0.003	co.002 - <0.003	co.002 - co.003
cu	<0.001 - 0.002	<0.002	co.002
Fe	0.016 - 0.057	0.026 - 0.049	0.025 - 0.033
Mn	<0.002 - 0.005	0.003 - 0.004	0.003
zn	<0.001 - 0.037	0.002 - 0.040	0.001 - 0.020

ranged from 289 to 6440 cfs in 1987 through 1990. Discharge was typically lowcst during the late summer, increased in the early fall, then dcclincd ovcr lhc wintcr. Highcst flows usually occurred during the spring runoff or from April through June.

Surface water tcmpcraturcs rangcd from 50°F to 62°F and 49°F to 65°F in Nelson Springs and Buckskin Creek, rcspectivcly (Figures 4.4 and 4.5). Similar lrends wcrc noted by thc USBR in previous years (USBR 1990). Nachcs River tcmpcraturcs arc typically 3°F to 10°F coolcr, cxcept during June through September, and ranged from 42°F to 64°F during 1991. Watcr tcmpcraturcs from the proposed surface water sources wcrc highcr than tcmpcraturc critcria suggcstcd for early stagcs of cgg incubation for salmonids (i.e., >58°F, Piper et al. 1982) during the latc summcr.

4.2.2 Groundwater Characteristics

Water quality paramctcrs wcrc mcasurcd from lhrcc diffcrent groundwatcr sources at Nelson Springs: 1) a shallow ~15-ft aquifcr locatcd bclow a doublc-widc trailcr, 2) the tcst wcll drilled by CH_2M

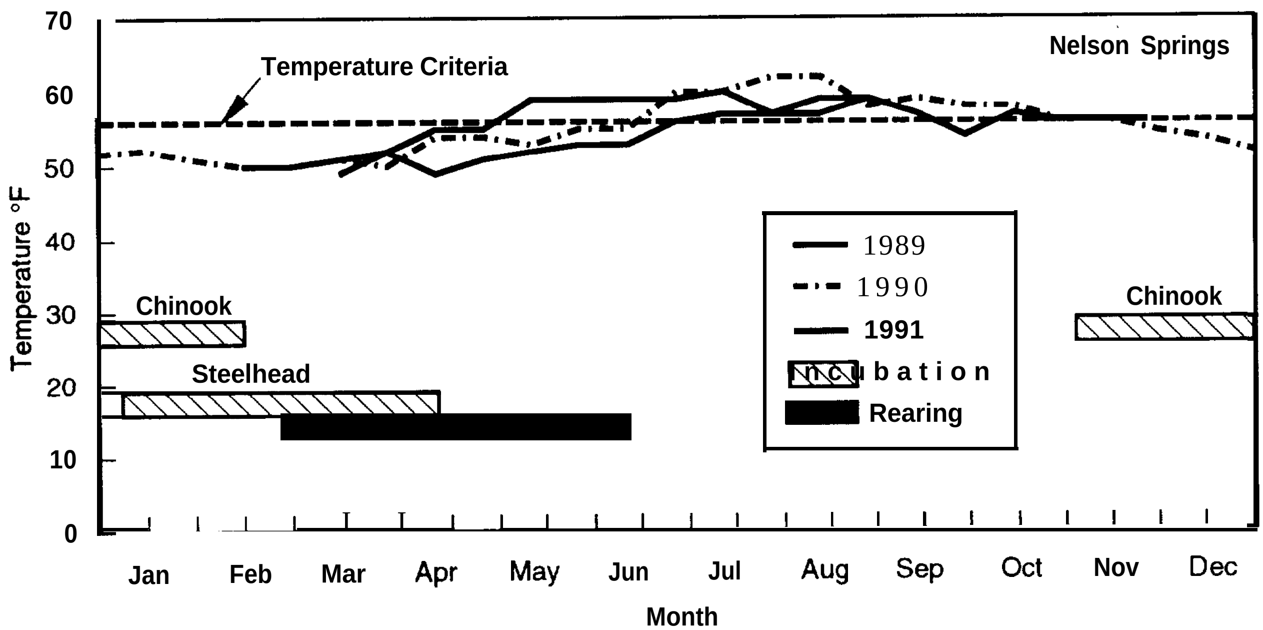


Figure 4.4. Incubation and Rearing lntcrvals for Chinook Salmon and Steclhead and Rclationship to Scasonal Walcr Tcmpcraturcs in Nclson Springs

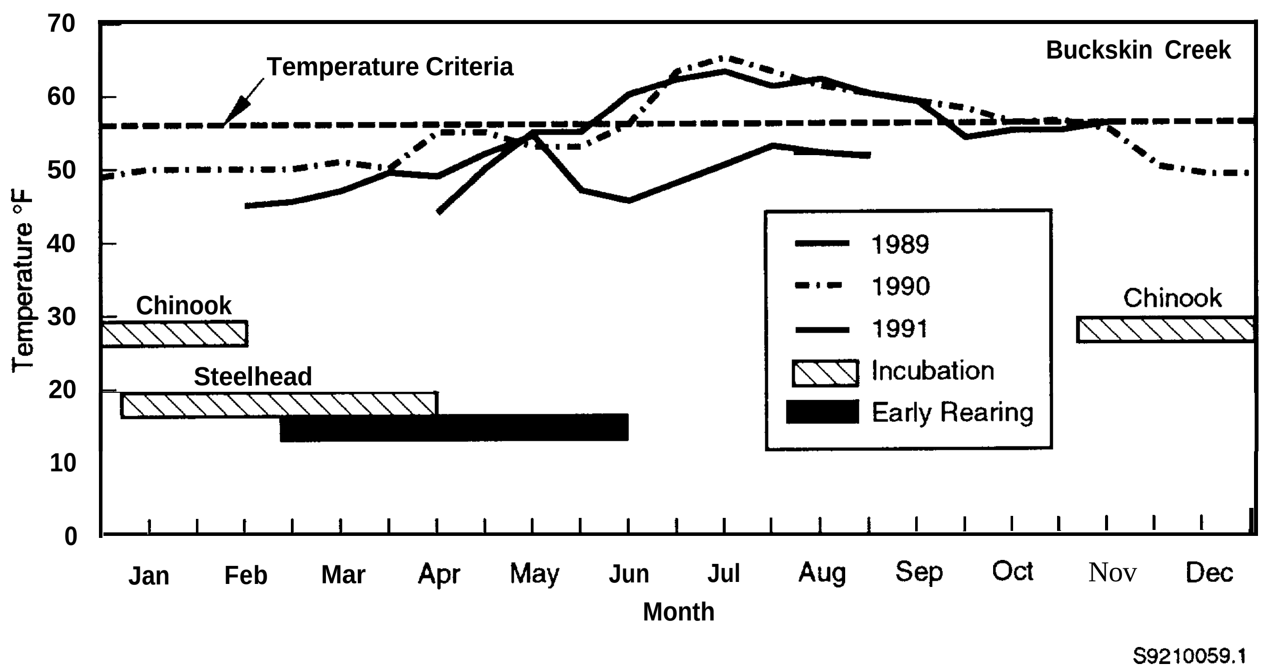


Figure 4.5. Incubation and Rcaring lntcrvals for **Chinook** Salmon and Stcclhcad and Relationship to Scasonal Watcr Tcmpcraturcs in Buckskin Crcek

Hill, and 3) the deep aquifer (-120 ft) located below a golf course. Characteristics of these well water sources are summarized in Table 4.8. Concentrations of some metals (i.e., aluminum, magnesium, manganese, and zinc) and nitrate appeared high. For example, zinc concentrations were elevated above surface water standards at the golf course well, even at the relatively high hardness value.

Water temperature of the shallow unconfined aquifer at Nelson Springs was about 54°F. The temperature of the deep aquifer below the golf course was estimated at 62°F to 64°F, based on data collected from nearby landowners.(a) Thus, this source also exceeds the temperature criteria for incubation of salmonids.

4.2.3 Hatchery Effluent

Effluent from the facility would discharge into Nelson Springs then to the Naches River. Resulting nitrogen and phosphorus levels were first calculated for Nelson Springs receiving hatchery effluent, and then for the Naches River using Nelson Springs as the source (Table 4.9). Calculations based on a low flow of 8.8 cfs indicated that resulting nitrogen concentrations in Nelson Springs could exceed the recommended levels during March, June, and July. Thus, there exists a potential for enhanced algae growth to occur during these months. Estimated nitrogen concentrations downstream in the Naches River would exceed limits during March, September, and November. Phosphorus concentrations in the Naches River could exceed the established criteria during March, June, and July. However, ambient phosphorus levels already exceed recommended limits during these periods and would not be increased by the input of effluent discharged to Nelson Springs.

Table 4.8. Major Water Quality Parameters Measured for Three Well Sites at Nelson Springs by Pacific Northwest Laboratory in 1992. Bioassays were conducted using water from the shallow aquifer well (n=5). All values are mg/L.

Parameter	CH_2M Hill Well, March 1992	Shallow Aquifer Well, Feb. - April 1992	Deep Aquifer Well, Julv 1992
Al	0.052	0.018 - 0.026	0.048
Ca	39.75	no data	38.33
Cl	9.16	no data	9.72
Cr	0.004	no data	<0.003
c u	co.002	no data	<0.002
Fe	<0.006	<0.006 - 0.017	0.002
K	6.58	no data	7.61
Mg	17.36	4.93 - 5.33	18.04
Mn	0.016	<0.001 - 0.002	0.006
Na	15.48	no data	15.83
NO_3	4.28	3.48 - 4.11	4.90
pH	7.5	7.6 - 8.6	7.2
SO_4	27.38	no data	26.15
Zn	0.073	0.0 13 - 0.020	0.112
Alkalinity	196	64-71	182
Hardness	195	63 - 77	173

(a) Doug Kunkel, Hydrologist, CH_2M Hill, Seattle, Washington: personal communication with D. D. Dauble, Pacific Northwest Laboratory, Richland, Washington, May 1991.

Table 4.9. Predicted Nutrient Inputs from the Proposed Fish Production Facility at Nelson Springs. Concentrations are in mg/L.

	Low Flow
Percent effluent	64
Effluent nitrogen	0.36
Effluent phosphorus	0.019
Receiving nitrogen	0.06
Resultant nitrogen	0.25[a]
Resultant phosphorus	0.016

(a) Occasionally exceeds recommended limits in receiving waters.

4.3 Oak Flats Site

Potential water sources for the Oak Flat Site include surface water from the Naches River and groundwater from an underlying aquifer.

4.3.1 Surface Water Characteristics

Limited water quality analysis completed by the USBR at Oak Flats in 1988 and 1989 revealed only that concentrations of aluminum and manganese exceeded ADFG criteria. PNL analysis of the Naches River in 1991 and 1992 indicated that aluminum, iron, manganese, and zinc were sometimes elevated during the spring runoff period (Table 4.10). The USGS conducted water quality analysis for metals at Oak Flats from April 1987 to March 1990. Of the parameters measured, only nickel and zinc exceeded aquaculture criteria during the study (Table 4.11).

Flows of the Naches River near Oak Flats appear to be adequate to meet the hatchery requirement of up to 44 cfs. Simulated monthly mean flows at Oak Flats over a 50-year period ending in 1987 ranged from 2945 cfs in May to 265 cfs in September. Low flows, less than 50 cfs, have been known to occur in July of extremely dry years (Figure 4.6). The Naches-Selah Irrigation District currently diverts approximately 175 cfs of Naches River water from a point downstream from the proposed facility. This flow has the irrigation canal withdrawal factored in. The irrigation district is considering moving the point of diversion to the site of the Old City of Yakima intake. A pipeline would transport water to the existing canal near the Highway 4 10 overpass (USBR 1990). A portion or all of the facility effluent water could be discharged into the pipeline and would not enter the Naches River downstream of the proposed facility.

In 1991 mean surface water temperatures ranged from 45°F to 64°F during June through September. In 1992, temperatures ranged from 58°F to 70°F over the same period. The USBR currently collects daily temperature data from a Hydromet station located near the Oak Flats Site. The station has been in operation since January of 1991 (Figure 4.7).

4.3.2 Groundwater Characteristics

Initial groundwater analysis was completed in 1989 by the USBR for two production wells drilled at the Oak Flats Site. Well PW-2 is located near the west end of the site, and PW-1 is located near the center of the site. Of the parameters analyzed from well PW-1, aluminum, dissolved oxygen, hydrogen sulfide, iron, nitrogen gas, and sodium were above ADFG aquaculture criteria (USBR 1990). Testing of well PW-2 indicated that aluminum, chromium, hydrogen sulfide, iron, manganese, nitrogen gas, and zinc were elevated. Because the wells were not pumped for long periods of time, levels of chromium and zinc may be residues from the drilling activity (USBR 1990).

Table 4.10. Surfacc Watcr Charactcristics for thc Nachcs Rivcr at Oak Flats According to Pacific Northwcst Laboratory and U.S. Burcau of Rcclamation. All values arc mg/L unlcss othcrwisc notcd.

Paramctcr	PNL, April-May 1991 (n=4)	PNL, May-July 1992 (n = 4)	USBR, 10-April-1989 (n = 2)
Al	0.0243 - 0.1142	<0.005 - 0.042	0.15
Br	<0.140 - <0.02	co.04 - co.05	--(a)
Ca	--	5.66 - 7.231	--
c l	0.648 - 0.68	0.87 - 1.41	0.35 - 0.709
Cr	<0.0025 - <0.0027	4004 - 0.003	0.002
Cu	<0.0013 - 0.0026	<0.0009 - <0.003	0.002
F	0.03 - 0.10	<0.01	--
Fe	0.0219 - 0.153	<0.005 - 0.054	0.13
K	co.09 - co.12	0.384 - 0.919	0.78
Mn	<0.0021 - 0.088	<0.006 - 0.001	0.02
Mg	--	0.985 - 1.357	1.34 - 1.7
NH_3	nd - <0.007	--	0.000 1
NO_3	0.019 - 0.49	0.43 - 0.91	0.01
NO_2	<0.02 - <0.08	--	--
Oxalatc	nd - <0.11	<0.21 - <0.29	--
PH	8.27 - 8.51	7.61 - 8.20	7.5 - 8.8
SO_4	2.45 - 2.58	2.95 - 3.09	2.4 - 3 .84
TDS	20-40	38.2 -42.8	49-57
Temp. (“F)	41-54	58 - 60.8	--
Zn	<0.0008 - 0.149	<0.0014 - 0.017	0.005
Alkalinity	20.5 - 87.9	17-67	39
Diss. oxygcn	12.1 - 12.15	7.7 - 10.8	11.6
Hardncss	21.1 - 78.2	14 - 24	29

(a) -- = not mcasurcd.

Table 4.11. Mctals Analysis of thc Nachcs Rivcr at Oak Flats by the U.S. Gcological Survcy, April 1987 to March 1990

Paramctcr	Concentrution. mg/L	n
Cd	0.001 - 0.002	15
Cr	<0.001 - <0.005	5
Cu	<0.001 - <0.010	17
Fc	0.013 - 0.035	3
Hg	<0.0001 - 0.0002	15
Mn	0.002 - 0.004	3
Ni	4.10	3
Pb	<0.00 1 - <0.010	17
Zn	co.003 - 0.018	3

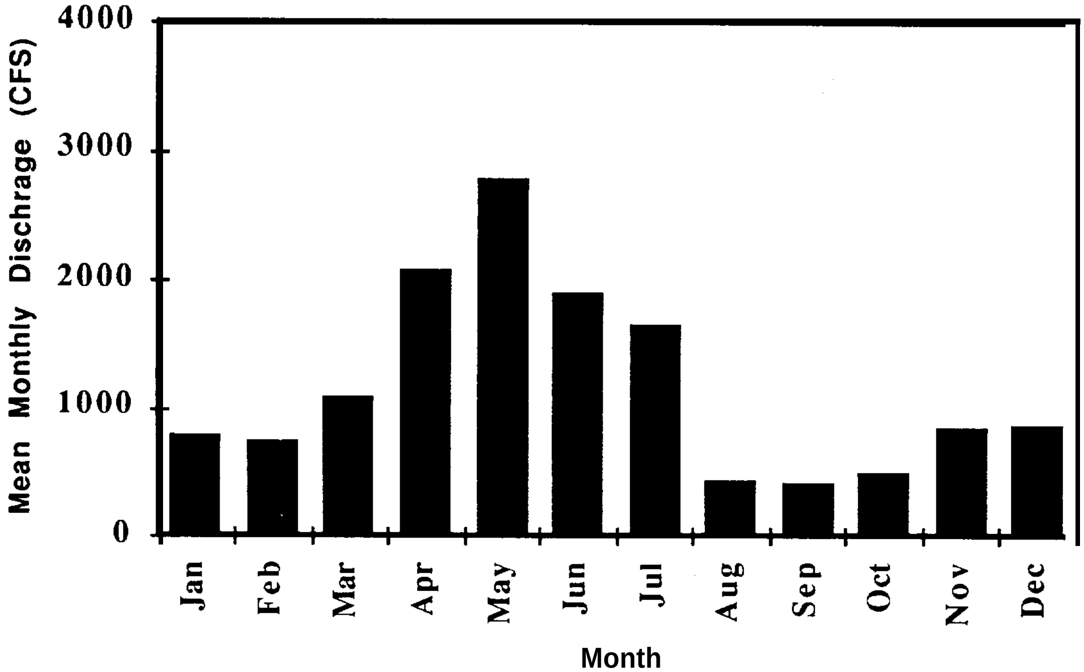


Figure 4.6. Simulated Average Monthly Flows (in cfs) for the Nachcs River at Oak Flats, 1926 to 1987 (from USBR 1990)

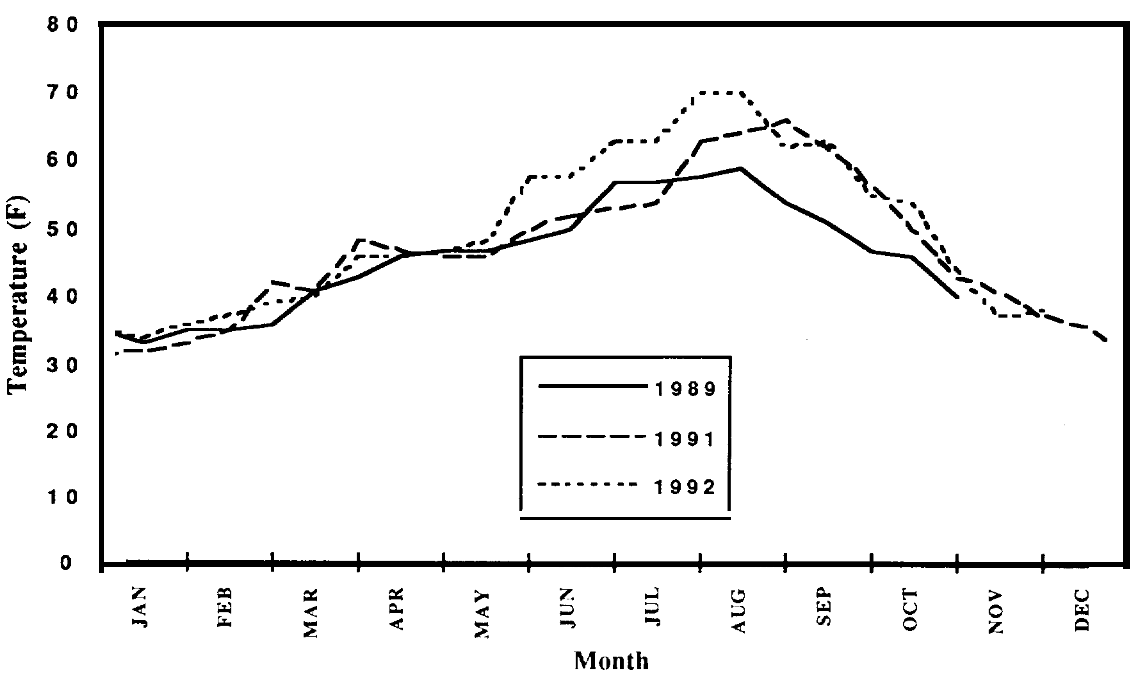


Figure 4.7. Average Monthly Water Tcmpcraturcs from the Nachcs River near Oak Flats

A third production well (OF-l) was drilled near the center of the site in May of 1991 by CH_2M Hill. Basalt bedrock was encountered at a depth of 87 ft; drilling continued to a final depth of 114 ft below ground surface (CH_2M Hill 1991). PNL collected water samples from well OF-l in 1991. Parameters that exceeded aquaculture criteria during this evaluation were aluminum, chloride, and zinc. Water quality characteristics for the wells are summarized in Table 4.12.

Hydraulic testing from the two wells drilled by the USBR in 1989 produced low flows. For example, well PW-I yielded only 75 gpm and well PW-2 yielded about 100 gpm with a 15-ft drawdown. Additional testing with smaller capacity pumps revealed that each well was capable of producing up to 100 gpm of sustained pumping (CH_2M Hill 1991). The third well (OF-l) drilled in 1991 by CH_2M Hill yielded about 300 gpm of sustained pumping. Based on seismic investigations, it was recommended that up to 15 additional wells ranging in depths from 60 to 90 ft be drilled at the site.

Groundwater temperature averaged 5 1.6˚F during a 4-week sustained pumping test at well OF-l in July and August of 199 1. Naches River water temperatures averaged 64.0˚F during the 4-week test or about 12.4˚F higher than groundwater temperatures. No evidence of infiltration of warmer surface water was evident during the study (CH_2M Hill 1991). Well water temperature was above criteria from late August through November. Thus, water chillers would be required to cool well water during the salmonid incubation period. From December to March surface water will be used with well water for incubation. Temperature data measured at wells PW- l and PW-2 during 1989 indicated groundwater temperature at 5 1 “F. PNL water quality evaluations of well OF-l in August 1991 indicated a groundwater temperature of 54.6˚F.

Table 4.12. Major Water Quality Parameters Measured at Three Well Sites by Pacific Northwest Laboratory and USBR from 1989 to 1992 at the Oak Flats Site. Bioassays were conducted using well OF-l in 1992. All values are mg/L except as noted.

Parameter	PNL, August 6, 1991, well OF-l	PNL (n=5), Feb-Apr. 1992, well OF- 1	USBR, December 19, 1989, well PW-1	USBR, December 19, 1989, well PW-2
Al	0.0135	0.014 - 0.20	0.077	0.082
Ca	--[(a)]	9.051 - 10.01		
Cd		--	<0.002	0.02
Cl	6.55	0.48 - 7.76	0.1	0.1
Cr	<0.0044	co.003 - 0.005	0.006	0.018
c u	<0.0021	<0.001 - <0.002	0.002	0.003
Fe	0.0104	<0.006 - 0.021	0.35	4.15
K	0.00	3.176 - 3.347	2.35	3.13
Mg		2.188 - 2.276	2.43	2.31
Mn	0.0073	0.002 - 0.004	0.005	0.085
Na		23.72 - 25.65	4.83	20
NO_3	0.05	0.05 - 0.58	0.08	0.01
pH	8.46	7.75 - 8.55	8.41	8.25
SO_4	1.13	0.0 - 0.54	4.32	2.88
Zn	0.0042	0.002 - 0.121	0.005	0.15
Alkalinity	87.9	85 - 135	52	69
Hardness	78.2	38 - 40	47	29
Temp. (“F)	54.6	55.4 - 56.6	51	51
H_2S			0.01	0.01
Diss. oxygen	8.4	4.1-10.1	3.5	1.5

(a) -- = not measured.

4.3.3 Hatchery Effluent

Calculations for the Oak Flats Site considered both monthly average low flow and lowest monthly mean flow (Table 4.13). The predicted nutrient concentration of nitrogen slightly exceeded the established criteria. It is unlikely that these slight increases would provide a nutrient regime that would result in problem algae growth.

4.4 Wapato Site

Potential water sources for the Wapato Site include surface water from the Wapato Canal. No groundwater would be required for fish production at this site. However, a survey in 1991 by CH_2M Hill indicated that groundwater supplies at this site would be adequate to meet the domestic water supply (CH_2M Hill 1991).

4.4.1 Surface Water Characteristics

The USGS conducted water quality analysis from the Yakima River near Wapato from 1975 to 1985 and from 1987 to 1991 (Rinella et al. 1992b). Collectively, their results showed that levels of manganese were sometimes slightly elevated (Tables 4.14 and 4.15). The USBR analyzed water quality in August of 1988 near Sunnyside Dam. Results indicated that aluminum and manganese sometimes exceeded ADFG aquaculture criteria (USBR 1990). PNL collected additional samples during the spring of 1991 at Wapato. Only aluminum and zinc slightly exceeded aquaculture criteria (Table 4.14).

PNL conducted additional studies at Wapato in the spring of 1992 to determine if turbidity and suspended sediments might adversely impact fish reared at the site. These studies were performed during the period in which juvenile salmonids would be acclimated. Results of the tests indicated turbidity values rose from 9.6 to 8.9 NTUs from April to June. Total suspended matter also increased from 6.4 to 11.8 mg/L during the sampling period. These parameters were below the established criteria (see Appendix B).

The Wapato Canal operates from March through November of each year. The average flows range from 500 cfs in March to 2000 cfs in June. Yakima River flows average 3000 to 3500 cfs at Parker 2.5 miles downstream of the Wapato facility during the spring months. Acclimation ponds and raceways would require up to 60 cfs from the canal flow. Water would be pumped from an existing pump station located downstream of the drum screens to the acclimation ponds, then back to the Wapato Canal upstream of the drum screens.

Table 4.13. Predicted Nutrient Inputs from the Proposed Fish Production Facility at Oak Flats. Concentrations are in mg/L and were based on a low flow of 172 cfs and mean flow of 344 cfs.

	Low Flow	Mean Flow
Percent effluent	16	9
Effluent nitrogen	0.83	0.83
Effluent phosphorus	0.03	0.03
Receiving nitrogen	0.02	0.06
Resultant nitrogen	0.15[a]	0.13[a]
Resultant phosphorus	0.022	0.012

(a) Occasionally exceeds recommended limits for receiving waters.

Table 4.14. Historical Surface Water Quality Parameters Measured from the Yakima River near the Wapato Site. All values are mg/L.

Parameter	USGS[a], 1975 - 1985 (n=24 - 60)	PNL, April 1991 to June 1991 (n=4)	USBR, Sunnyside Dam, August 2, 1988 (n=1)
Al	--[b]	0.023 - 0.0309	0.2
Cd	<0.001	--	0.002
Cl	2.80	0.65 - 1.78	1.06
Cr	<0.0001	<0.002 - <0.003	0.002
Cu	0.002	<0.001 - <0.002	0.002
F	--	0.04 - 0.08	0.1
Fe	0.04	0.031 - 0.0491	0.18
K	1.30	N/A	1.17
Mg	4.00	N/A	3.89
Mn	0.10	5.876 - 6.582	0.02
Na	6.30	N/A	4.83
NH_3	0.09	<0.007 - 0.029	0.0002
NO_2		<0.02 - <0.080	0.01
NO_3	0.17	<0.03 - 0.47	0.12
Oxalate	--	<0.11 - <0.12	
pH	7.8	8.5 - 9.3	7.6
SO_4	4.20	2.42 - 3.72	3.36
TDS	81	40 - 50	64
Zn	0.005	<0.0008 - 0.0310	0.005
Alkalinity	52	36 - 65	
Hardness	12	35 - 92	
Diss. oxygen	11.8	12.8 - 14.0	9.6

(a) USGS = median values.
(b) -- = not measured.

Table 4.15. Metals Analysis of the Yakima River at Wapato by the U.S. Geological Survey, April 1987 to February 1991

Parameter	Concentration, mg/L	n
Cd	0.0001 - <0.005	30
Cr	0.001 - <0.005	24
Fe	0.015 - 0.150	21
Hg	<0.0001 - 0.0002	22
Mn	0.005 - 0.022	21
Ni	<0.001 - <0.01	19
Pb	<0.001 - <0.010	12
Zn	<0.003 - 0.040	22

The USGS WATSTORE database contains data on water temperature from 1987 to 199 1 at Union Gap (RM 106.8). Temperatures averaged 43°F in March to 52°F in late May. The USBR operates a Hydromet station recording flow and temperature at Parker, collecting temperature data since 1987. During the S-year period, average water temperature exceeded the recommended rearing temperature of 58°F in May of 1992 (Figure 4.8).

4.4.2 Hatchery Effluent

The release of hatchery effluent upstream from the facility intake could potentially increase the amount of suspended matter and turbidity values in the canal. However, the effluent may actually have lower suspended solids and turbidity because of settling effects of the pond. The reuse of canal water (less than 10%) for fish acclimation is not considered to be detrimental to receiving waters downstream of the Wapato Site. Thus, regardless, effluent treatment is planned for wastewater discharged into the canal.

4.5 Prosser Site

Water sources for the Prosser Site include surface water from the Yakima River and Chandler Canal, and groundwater from an underlying aquifer.

4.5.1 Surface Water Characteristics

Water quality samples were collected from the Chandler Canal in the fall of 1988 by the USBR (1990). Water quality parameters measured that did not meet ADFG criteria included aluminum, chloride, hydrogen sulfate, and manganese (Table 4.16). PNL collected water quality samples in May and June 1991 from the Yakima River at Prosser. Water quality parameters that exceeded existing aquaculture criteria included manganese, aluminum, and nitrates (Table 4.16).

Additional surface water samples were taken by the USGS near the headworks of the Chandler Canal from 1974 to 1985. The results of these investigations showed that only chloride and cadmium slightly exceeded aquaculture criteria (Table 4.16). The USGS also analyzed quality of the surface water of the Yakima River at Kiona from 1986 to 1991 (Rinella et al. 1992b). The results of this analysis are shown in Table 4.17 and indicate that metals concentrations in the lower Yakima River are fairly low.

PNL conducted additional studies in 1992 to determine if turbidity and total suspended matter were a concern at the proposed fish holding facilities near Prosser. The tests were conducted under the premise that fall chinook salmon would be reared from March to May. The turbidity values exceeded Washington State criteria for Class A waters (i.e., < 5 NTU over background), but were below 25 NTU, which is known to cause gill damage and retard growth of salmonids (Council 1992). Suspended matter and settleable matter values were also below established criteria (Figure 4.9). Annual and monthly trends indicated that total suspended sediments and turbidity values are highest during the spring period and lowest in October and November (Figure 4.10). All measurements are summarized in Appendix B.

Average surface discharges at Prosser Dam range from 400 to 1600 cfs during the fall. A minimum instream flow of 200 cfs is required downstream from Prosser Dam from September 1 to November 30 to facilitate adult passage (YIN 1990). Flow in the Chandler Canal fluctuates depending on river flows, irrigation, and power generating needs. The canal normally diverts more water in the spring months. Up to 13 cfs of canal water is required during April. Hatchery withdrawals would not affect the minimum flow requirements for adult fish passage.

Optimum temperatures for spawning salmon and steelhead range from 42°F to 56°F, including an upper limit of 55°F for spawning temperature (Armour 1991). Average water temperatures at Prosser range from 75°F in early August to near 50°F in late October. Adult fall chinook generally start appearing at Prosser in mid-August. Thus, temperatures sometimes exceed the recommended holding conditions for fall chinook and coho of 55°F until about mid-October (see Figure 4.11).

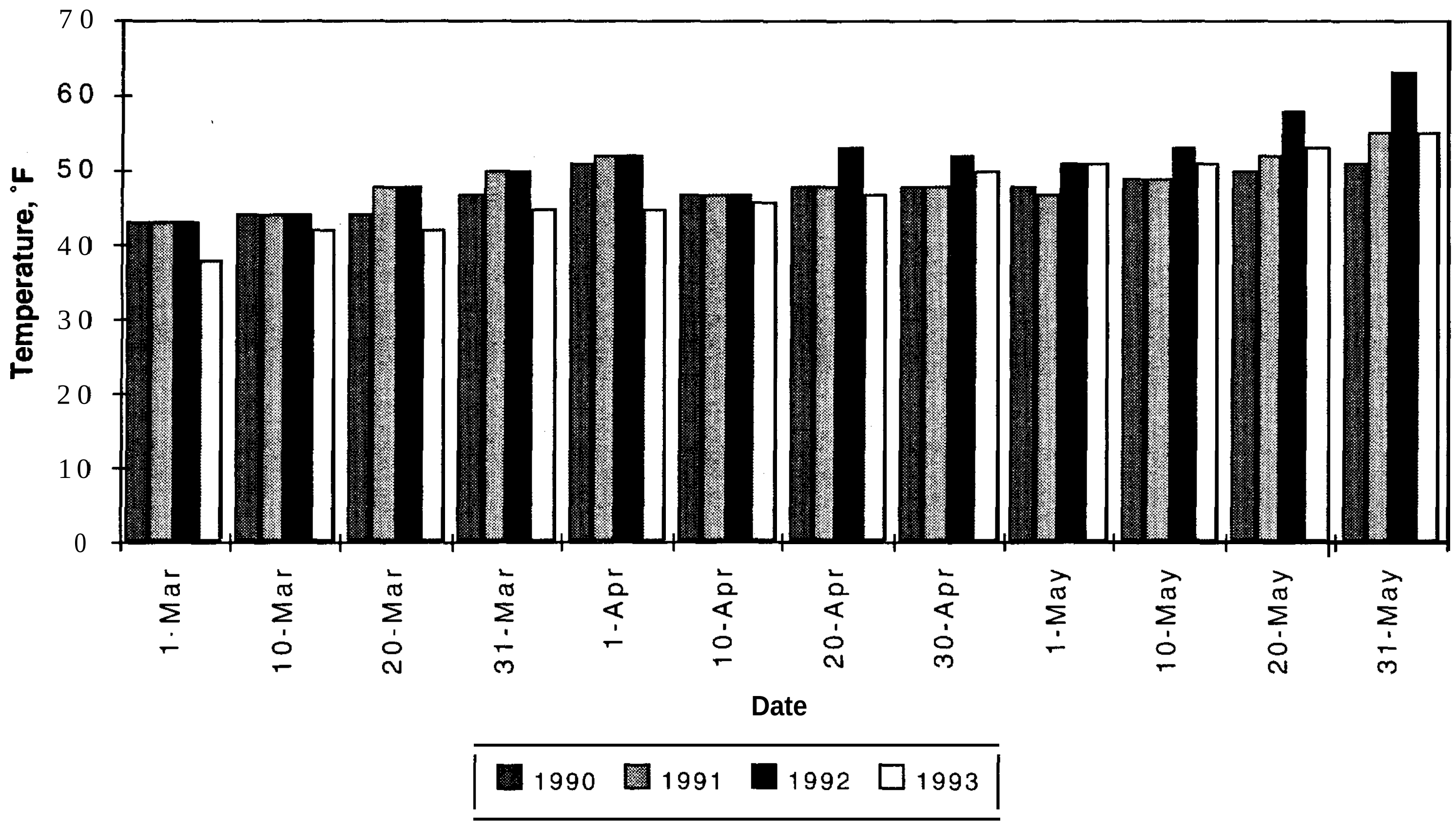


Figure 4.8. Average Water Temperature Profiles during the Acclimation Period at Wapato, from 1990 to 1993

Table 4.16. Historical Surfacc Watcr Quality Paramctcrs Mcasurcd from the Chandlcr Canal ncar Prosscr, Washington. All valucs arc mg/L.

Paramctcr	USBR, August 2, 1988 (n=1)	USGS, 1974-1985 (n=24-60)	**PNL,** May-June 1991 (n=4)
Al	0.44	--[(a)]	0.018 - 0.045
Chloride	5.32	4.60	2.5 - 4.0
Cr	0.002	0.001	<0.002 - <0.003
Cu	0.002	0.003	<0.0013 - <0.0016
F	0.18	--	nd - 0.140
Fc	0.42	0.03	0.029 - 0.085
K	3.13	2.70	nd - 0.28
Mn	0.14	0.008	0.012 - 0.028
Mg	10.34	7.70	--
Na	16.3	12.00	--
NH_3	0.0008	0.02	nd - <0.007
NO_2	0.04		<0.02 - <0.08
NO_3	1.12	0.74	0.201 - 3.960
Oxalate	--		nd - <0.12
pH	8.37	-7.70	8.37 - 8.68
SO_4	16.8	11	nd- 11.64
TDS	174	164	70 - 100
Alkalinity	126	90	45 - 92
Diss. oxygen	11.3	10.2	7.9 - 12.5
Hardness (as Ca CO_3)	27.1	20	64 - 84

(a) -- = not mcasurcd.

Table 4.17. Mctals Analysis of thc Yakima Rivcr at Kiona by thc U.S. Gcological Survcy, Novcmbcr 1986 to May 1991

Paramctcr	Concentration. mg/L	n
cd	<0.0001 - 0.003	14
Cr	<0.001 - co.005	8
Cu	<0.001 - <0.005	15
Fe	0.008 - 0.046	6
Hg	<0.0001 - 0.0003	11
Mn	<0.001 - 0.034	5
Ni	<0.001 - <0.10	5
Pb	<0.001 - co.01	12
Zn	<0.003 - 0.14	6

4.5.2 Groundwater Characteristics

Thc Prosscr Site is locatcd abovc a thick alluvial-fill aquifcr with a high capability for yielding water. Groundwatcr evaluation studics conductcd by CH_2M Hill in 1989 indicate that the aquifer is capable of supplying more than thc rcquircd volumc of watcr for plannccl fish production. One production well capablc of 3-cfs sustainablc yicld cxists at thc Prosscr facility. Thc wcll was drilled in 1989 by CH_2M Hill and is locatcd ncar thc cxisting juvcnilc facility. Bascd on aquifcr tcsting, CH_2M Hill recommended that an additional wcll bc drillcd to maximizc wcll cfficicncy (CH_2M Hill 1991). Recharge of the aquifcr is made up of irrigation rcturn watcr, lcakagc from thc Chandlcr Canal, and, to a lesser cxtcnt, infiltration by thc Yakima Rivcr.

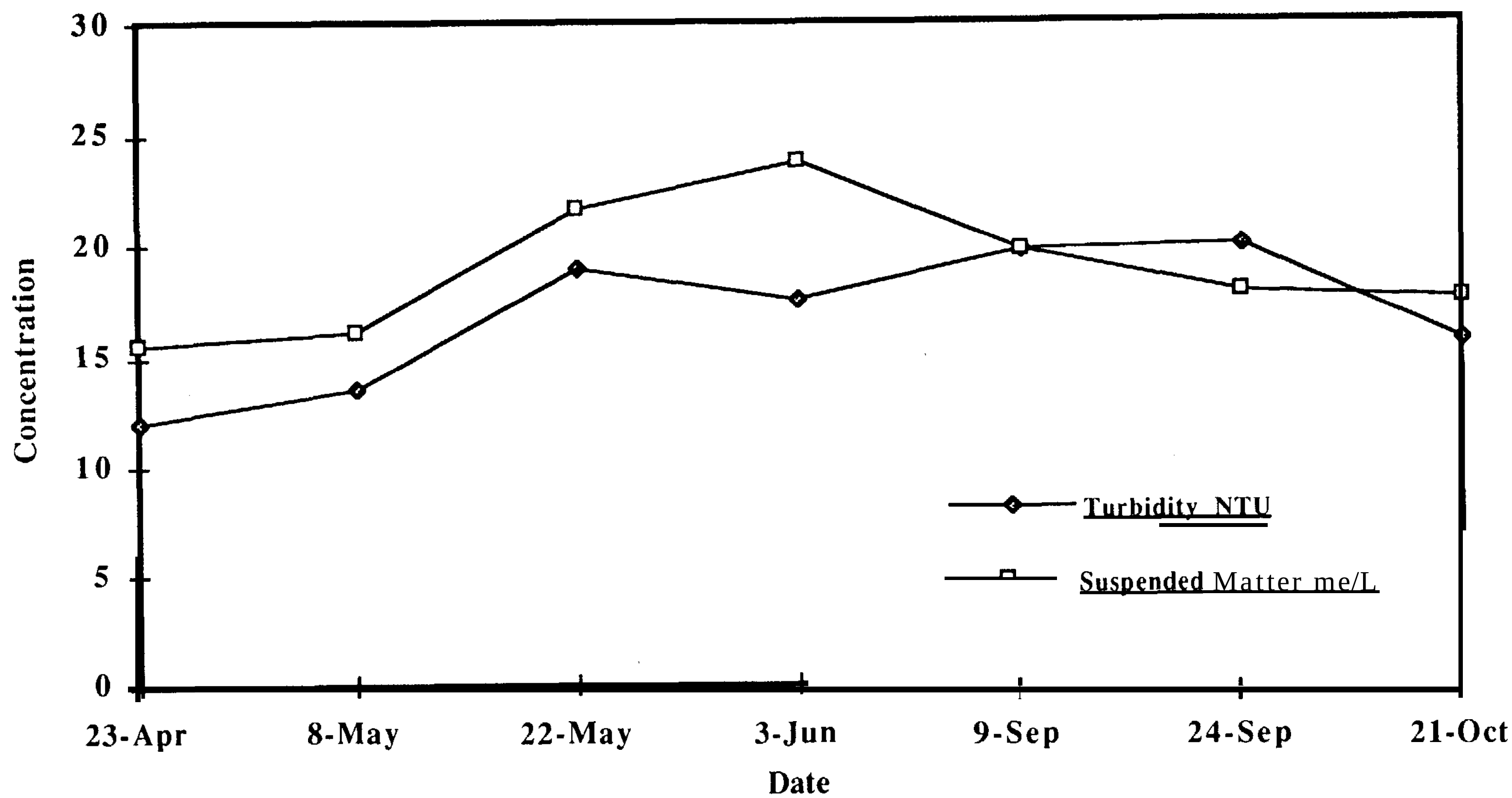


Figure 4.9. Turbidity and Total Suspended Matter Parameters Measured in the Chandler Canal during 1992

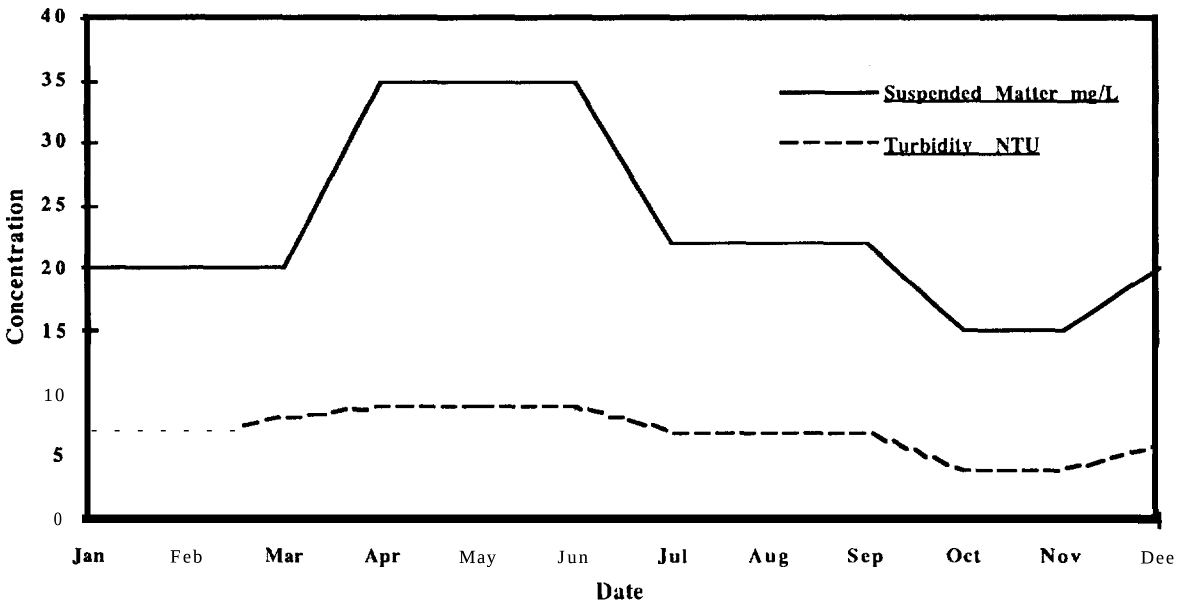


Figure 4.10. Historical Trcnds for Turbidity and Total Suspcndcd Scdimcnts at Prosscr (from Rinclla ct al. 1992a)

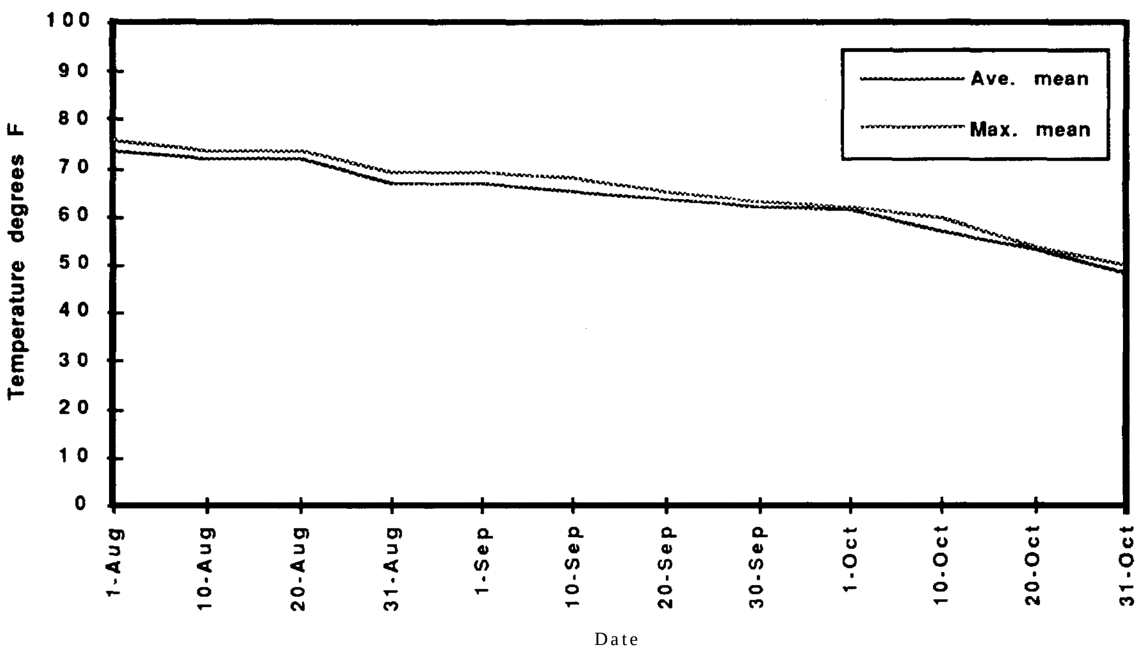


Figure 4.11. Avcragc and Maximum Watcr Tcmpcraturc Profilcs in Rclation to the Adult Salmonid Holding Pcriod at Prosscr Dam from 1988 to 1993

Groundwater characteristics from the existing well at the site are summarized in Table 4.18. The well's water quality was tested in December 1989 by the USBR and in 1991 by PNL. In addition PNL analyzed water samples from the well during incubation tests with rainbow trout eggs. Parameters that did not meet ADFG criteria included aluminum, carbon dioxide, magnesium, chloride, and dissolved oxygen. However, none of the parameter levels present would be considered to be detrimental for aquaculture purposes.

A groundwater temperature of 53°F was taken in December of 1989. During the 6-week aquifer test from September to October 1991 the groundwater temperature rose from 57°F to 58.3°F or an increase of 0.3 to 0.4°F for each week of pumping. Groundwater temperature averaged 58°F. It has been recommended that chilled well water be used as the water source until river water reaches 55°F. Yakima River water temperatures are expected to be in the optimum range during fall chinook early rearing from February to April.

Two wells were drilled in 1989. The first well (P-PW- 1) was abandoned because of insufficient yield. P-PW-2 was drilled approximately 150 ft east of the juvenile facility to a final depth of 103 ft. A 6-week aquifer test was conducted a rate of 4.9 cfs. Sequential testing indicated that this well could be pumped at a rate of 6.6 cfs for short periods but operation at this rate was not recommended because of high entrance velocities in the well screen. A final pumping rate of 2.9 cfs was recommended for continuous pumping. Based on this evaluation, one additional production well would be required to meet the water demand at this facility.

Table 4.18. Major Well Water Quality Parameters Measured at Prosser by Pacific Northwest Laboratory and U.S. Bureau of Reclamation. All values are mg/L unless noted.

Parameter	USBR, December 20, 1989 (n=1)	PNL, October 1991 to April 1992 (n=5)
Al	0.015	0.07 1 - 0.086
Ca	--[a]	60.5 - 66.4
Cl	12.05	0.32 - 14.03
CO_2	20.6	--
Cr	0.003	<0.003 - <0.008
c u	0.005	<0.001 - <0.005
F	0.34	0.33
Fe	1.35	co.002 - 0.007
K	4.30	0.00 - 4.30
Mg	15.90	<0.003 - 16.30
Mn	0.015	0.002 - 0.003
Na	22.50	21.1 - 22.9
NH_3	nd[b]	nd
NO_3	3.55	0.30 - 26.66
pH	7.35	7.18 - 8.48
SO_4	36.50	0.00 - 42.83
TDS	324	
Zn	0.01	0.002 -0.007
Alkalinity	231	231 - 290
Diss. oxygen	5.5	6.7
Hardness (as Ca C03)	226	240 - 266
Temperature (°F)	53.1	58.3 - 59

(a) -- = not measured.
(b) nd = none detected.

4.5.3 Hatchery Effluent

Increased concentrations of nitrogen and phosphorus in lhc Yakima Rivcr wcre not estimated to occur as a result of hatchcry operations. Thc nitrogcn conccntration (0.8 mg/L) at this site already exceeded the rccommcndcd lcvcl of 0.10 mg/L (Tablc 4.19).

4.6 Acclimation Ponds

Water quality was samplcd in tributarics and thc mainstrcam Yakima Rivcr near sclccted acclimation pond sites. Additional informalion on flow and Lcmpcraturc charactcristics at these sites is contained in Appcndix B.

4.6.1 Surface Water Characteristics

We reviewed available litcraturc to gathcr historical data on watcr quality characteristics near the 16 proposed acclimation sites. Limitcd watcr quality data wcrc obtaincd. PNL also collcctcd water samples for analysis during June and July of 1992. Sitcs invcstigatcd included uppcr and lower Toppenish Creek, Nachcs River near Oak Flats, and thc Yakima Rivcr al Horn Rapids Dam. Rcsults from thcsc and othcr historical information on surface watcr quality arc prcscntcd in Tablc 4.20.

4.6.2 Acclimation Pond Effluent

Nutrient loading to tributary crccks from opcration of acclimation pond sitcs was estimated using an effluent volume of 1.2 cfs pcr pond and thc lowcst strcam flow valucs rcportcd for March, April, and May (BPA 1992). Only one uppcr tributary sitc was cstimatcd to cxcccd rccommcndcd lcvcls for nitrogen or phosphorus. Thus, it is highly unlikcly that any problcms involving cxccssivc nutricnts and resulting algae growth would be cncountcrcd in rccciving watcrs downstrcam of acclimation pond dischargcs.

The additive input of cfflucnts from all proposcd fish culturc facilitics, including acclimation ponds, was also analyzed lo assess the potcntial for cumulativc cffccts to thc Yakima Rivcr and its tributaries (BPA 1992). Results indicated that hatchcry cfflucnts would not advcrscly impact thc aquatic ccosystem as a rcsult of incrcascd nutricnt loading. Any potcntial impacts would bc mitigatcd by grcatcr than minimum flows and bcst practice hatchcry managcmcnt. For small strcams, any incrcasc in nutrients would be localized and of short duration, In addition, any input to low-nutrient hcadwatcr strcams could potentially benefit fish production.

Table 4.19. Prcdictcd Nutricnt Inputs from thc Proposcd Fish Production Facility at Prosscr. Conccntrations arc in mg/L and wcrc based on a low flow of 162 cfs and mcan flow of 1665 cfs.

	Low Flow	Mcan Flow
Pcrccnt cfflucnt	2	9
Effluent nitrogen	0.83	0.83
Effluent phosphorus	0.04	0.04
Rccciving nitrogcn	0.8	0.8
Rcsultant nitrogcn	0.80[a]	0.80[a]
Rcsultant phosphorus	0.14	0.14

(a) Occasionally cxcccds rccommcndcd limits for rccciving waters.

Table 4.20. Historical Surface Water Quality Parameters at Acclimation Sites (from various sources)

Parameter	1962-1966 Teanaway R. ((1975 ave.)	1974-1975 Yakima R. at Thorp (ave.)	1980-1981 Toppenish Cr. near Fort Simcoe	1952-1970 Yakima R. at Cle Elum 9/15/70	1974-81 Yakima R. at Cle Elum Median	1963-1965 Little Naches River	1973-1975 Yakima River at Parker	May-July 1992 Lower Toppenish n=4	May-July 1992 Upper Toppenish n=4	May-July 1992 Horn Rapids n=4
pH	7.3	7.5		7.5	7.5			8.4 - 8.6	8.2 - 8.5	
Diss. oxygen	9.4	11.5		10.3	10.9			9.3 - 14.8	6.7 - 10.6	
ca	15.00	7.50		8.20	8.20		12.00	20.3 - 2.9	9.5 - 11.7	20.51 - 26.77
Na	3.30	2.00		2.60	2.60		6.30	11.0 - 12.8	4.9 - 6.2	11.68 - 14.75
NH_3				0.01	0.01		0.09	--	–	
K	0.40	0.30		0.70	0.70		1.30	2.9 - 8.4	1.9 - 8.3	2.512 - 7.973
$CaCO_3$	103	33		24	24			98 - 112	52 - 56	
SO_4	75.0	1.50		2.20	2.20		4.20	8.22 - 8.71	1.13 - 3.85	13.59 - 18.17
cl	1.20	1.50			2.80		2.80	3.8 - 10.3	0.95 - 8.39	5.67 - 7.47
F	0.10							0.11	0.05 - 0.12	0.15 - 0.19
Diss. solids	80.0							163 - 176	85.7 - 87.5	
NO_3	0.20	0.03		0.03	0.03		0.17	6.88 - 9.45	0.18 - 0.39	4.12 - 5.48
Mg	6.50	2.50		1.40	1.40		4.00	7.89 - 9.90	4.51 - 5.69	7.84 - 10.55
CU	0.01	0.001	0.001	0.01	0.01	0.03	0.002			
zn	0.01	0.01	0.003		<0.02	0.05	<0.02	0.001 - 0.053	0.001 - 0.037	0.001 - 0.015
Pb		0.015	<0.001				0.004	–		
Hg			<0.0001							
Fe			0.23					0.005 0.318	0.149 - 1.294	0.005 - 0.077
Mn			0.018					0.002 - 0.046	0.004 - 0.069	0.021 - 0.034
Al								0.005 - 0.225	0.005 - 0.334	0.005 - 0.04
Ni			0.001					–		
Cr	0.01		<0.01		0.01	<0.01	<0.02	0.003 - 0.005	0.003 - 0.004	0.003 - 0.005

5.0 Biological Screening

This section includes the results of studies used to evaluate the biological response of salmonids to surface water and groundwater supplies in the Yakima River Basin. These data, in addition to site-specific water quality and temperature data, were used to assess the suitability of potential water supplies for fish culture.

5.1 Live Box Studies

Survival and growth of fish held in live boxes near the proposed facilities were compared to that of fish held at the PNL hatchery. When fish were large enough and sufficient sample sizes were available, we also measured blood plasma parameters of juvenile chinook salmon and rainbow trout and compared their values to ranges reported for normal or healthy fish (Hille 1982; Wedemeyer et al. 1990). Values markedly outside this range were assumed to indicate stress resulting from environmental conditions present at the site.

5.1.1 Chinook Salmon, 1991

Survival of fish (n=200) held in live boxes at four proposed surface water sources from May 10 to June 12, 1991, was 94% at Cle Elum, 86% at Nelson Springs, 81% at Wapato, and 56% at Prosser. There were no mortalities noted for fish held in live boxes at Oak Flats during May. However, one live box at that site was lost to high water and the other was dewatered in a backwater area after the high water receded in early June. Survival of the reference population (n=100) of fall chinook salmon held at the PNL hatchery was 84%. The relatively high mortalities noted at Prosser were attributed lo stress from crowding and high water temperatures (i.e., > 22°C) that occurred in late May and June.

Condition factors (CF) for the various groups varied by location (Table 5.1). Mean CFs ranged from 7.4 to 9.9 on May 14 (2 weeks after fish were placed at the sites) and 6.4 to 10.3 on May 28. Highest CFs were noted for fish held in YIN net pens and at the Nelson Springs site, while the lowest CFs were noted for the Cle Elum and Chandler sites. Mean CFs generally declined during the 4- to 6-week holding period, and values appeared related to the amount of natural food present at the sites and frequency of supplemental feeding with a hatchery diet. Additional data on growth characteristics of the different groups are summarized in Appendix C.

Blood samples were taken from juvenile chinook salmon at three of the live surface water sites (not Cle Elum and Prosser) on June 11 to 13. Both live boxes at the Cle Elum Site were removed by vandals before the end of the exposure interval, and an insufficient number of fish were present at Prosser on that date to obtain a sample. Mean values of blood plasma parameters for each live box were compared with normal limits expected in clinically healthy juvenile salmonids (Table 5.2). Percentage hematocrit and leucocrit values (Table 5.3) of all groups of fish were within normal limits expected for healthy salmon. However, based on other blood plasma parameters (Table 5.4), the physiological condition of fall chinook salmon in the live boxes varied between locations.

Fish in the Oak Flats live boxes had the lowest protein value for any group at 1 .O g/dL and the lowest cholesterol value of 36 mg/dL. Their plasma potassium level of 8.0 meq/L was the highest of any group. Plasma calcium values were also the lowest for any of the groups at 8.0 mg/dL. Glucose, sodium, and chloride values for Oak Flats fish were within the normal range for healthy salmon. All of the blood plasma parameters for chinook salmon in the Nelson Springs live boxes were within expected ranges for healthy salmon (Table 5.2). Chinook salmon in live boxes at Wapato had mean protein levels of 1.6 g/dL and the lowest chloride level of any group at 117 meq/L. The mean potassium value of 6.1 meq/L was the highest for any group, but sodium and glucose values were within normal expected limits for healthy salmon (Table 5.2). All YIN net pen fish exceeded normal cholesterol values for salmon, with mean values ranging from 348 to 391 mg/dL. Mean plasma sodium values were also high, ranging from 158 to

Table 5.1. Mean Condition Factors (CF) for Juvenile Fall Chinook Held in Live Boxes at Various Sites in the Yakima Basin during 1991 (n= 20 except where noted in parentheses)

Site	14 May	28 May	11 June
Cle Elum	7.9	6.5	ns[a]
Oak Flats	8.3	7.1	ns
Nelson Springs	9.9	10.3	10.0
Wapato Canal	9.5	8.1	8.8
YIN net pens	10.9	ns	ns
Chandler Canal	7.4	6.4	6.9 (4)
PNL hatchery	8.2	8.3 (3)	9.3

(a) ns = not sampled.

Table 5.2. Approximate Normal Limits for Physiological Variables Expected in Clinically Healthy Juvenile Salmonids at 10°C (various sources)

Physiological Variable	Rainbow Trout, Wedemever et al. (1990)	Rainbow Trout, Hille (1982)	Coho Salmon, Wedemever et al. (1990)
Chloride, plasma (meq/L)[a]	84-132	84-147	122-136
Cholesterol, plasma (mg/100 mL)[b]	161-365	150-545	88-262
Glucose, plasma (mg/100 mL)	41-151	26-128	41-135
Potassium, plasma (meq/L)	4-5	1.3-11.3	4 - 6
Sodium, plasma (meq/L)	150-155	132-164	150-155
Calcium, plasma (meg/L)		2.6-12.8	2-6
Total plasma protein (g/100 mL)	1.4-4.3	2.8-6.0	2-6
Hematocrit, blood (%)	24-43		35-52
Leucocrit, blood (%)	0.8-1.8		0.8-1.8

(a) meq = milliequivalents where meq/L = mmol/L.
(b) dL = deciliter = 100 mL.

Table 5.3. Blood Hematocrit and Leucocrit Values for Juvenile Fall Chinook Salmon Held in Live Boxes at Various Locations in the Yakima River. Values as mean ± S.D. and represent 2 to 10 pooled samples of 8 to 13 fish each.

Date	Location	Mean Size, FL mm	% Hematocrit	% Leucocrit
5/1/91	YIN net pens	56	40 ± 3	ns[a]
5/15/91	YIN net pens	67	38 ± 0	ns
5/29/91	YIN net pens	73	41 ± 4	0.8 ± 0.4
6/11/91	Wapato Live Box	58	37 ± 0	0.7 ± 0.0
6/11/91	Oak Flats	62	35 ± 0	1.1 ± 0.0
6/13/91	Nelson Springs		43 ± 1	0.8 ± 0.2
6/18/91	PNL hatchery	62	38 ± 4	0.88 ± 0.50

(a) ns = no sample.

Table 5.4. Blood Plasma Parameters for Juvenile Fall Chinook Salmon Held in Live Boxes at Various Locations in the Yakima River During 1991. Values as mean ± standard deviation and represent 1- 10 pooled samples of 6-l 8 fish.

Date	Location	Glucose, mg/dL	Total Protein, g/dL	Cholesterol, mg/dL	Chloride, mmolL	Calcium, mg/dL	Sodium, mmol/L	Potassium, mmol/L
5/1/91	YIN Net Pens	72 ± 6	2.5 ± 0.1	349 ± 0	128 ± 4	12.2 ± 0.0	166 ± 5	5.1 ± 1.8
5/15/91	YIN Net Pens	80 ± 4	2.7 ± 0.2	348 ± 12	128 ± 2	10.1 ± 0.4	159 ± 3	4.9 ± 1.0
5/29/91	YIN Net Pens	93 ± 10	2.9 ± 0.3	391 ± 59	126 ± 4	10.4 ± 0.6	158 ± 5	4.0 ± 2.3
6/11/91	YIN Live Box	107f0	1.6 ± 0	nd[(a)]	117	nd	153	6.1
6/11/91	Oak Flats	63 ± 0	1.0 ± 0	36 ± 0	123 ± 0	8.0 ± 0	153 ± 0	8.0 ± 0
6/13/91	Nelson Springs	89 ± 5	2.1 ± 0.3	154 ± 66	122 ± 4	9.8 ± 0.4	154 ± 2	4.6 ± 1.9
6/18/91	PNL hatchery	71 ± 9	2.4 ± 0.4	203 ± 20	125 ± 3	10.5 ± 0.5	162 ± 4	2.6 ± 0.8

(a) nd = no data.

166 meq/L. However, these levels were within the "normal" values (i.e., 132 to 164 meq/L) reported by Hille (1982). All other blood plasma parameters of YIN net pen fish were within the expected range. The mean sodium value for PNL reference fish was 162 meq/L, while mean potassium values were the lowest of any of the groups at 2.6 meq/L. All other blood plasma parameters of the reference population were within expected ranges.

Plasma cholesterol values exhibited the greatest variation among the various exposure groups, ranging from 36 to 391 mg/dL. There also appeared to be a correlation between plasma glucose and cholesterol. Low cholesterol and glucose values were associated with fish groups having a low CF. Diet is the greatest source of variation for serum cholesterol (Barnhart 1969), with extreme values indicating either impaired lipid metabolism (too low) or dietary lipid imbalance (too high) (Wedemeyer and McLeay 1983). Chinook salmon from the YIN net pens were fed more often than fish in the live boxes and had highest cholesterol values. Low total protein values were observed in populations with the highest rate of mortality and lowest CFs. There was little change in the plasma calcium, sodium, and chloride among the live box groups. Potassium showed the highest variation of the four blood electrolytes measured. The reasons for this are unknown. Fish held at Oak Flats appeared stressed based on the suite of measurements taken.

5.1.2 Rainbow Trout, 1992

Exposure intervals in 1992 were shorter and later than planned because of difficulties in obtaining fish. Because of the late start date, survival of juvenile rainbow trout was not routinely monitored in 1992. However, 60% of the fish held at Horn Rapids and 100% of the fish held at Oak Flats were found dead on June 22 (the Oak Flats fish were in a backwater area, not the mainstem Naches River). Water temperatures at these locations were >26°C on those dates, levels known to be lethal to juvenile salmonids exposed for extended periods.

Fish held at Nelson Springs exhibited the greatest growth of any of the four populations held in surface water sources, while those held in the mainstem Yakima River near Horn Rapids Dam grew slowly and were noticeably thinner. Mean CFs for rainbow trout placed in the river on May 29 ranged from 8.3 to 9.2 on June 9 and declined slightly to 7.7 to 8.7 on June 22 (Table 5.5). Mean CFs for the reference population were higher on both dates. The highest CFs were noted for fish with the greatest potential for supplemental natural foods (Nelson Springs) and those with regular feeding (PNL hatchery). Additional data on growth characteristics of the different groups are contained in Appendix C.

Percentage leucocrit values for rainbow trout from Oak Flats on June 11 were the lowest of any group at 0.4% (Table 5.6). This level suggests that this group of fish was acutely stressed (Wedemeyer and McLeay 1983). Percentage hematocrit and leucocrit values of all other groups of fish were within normal limits expected for healthy salmon.

Before being placed in live boxes, juvenile rainbow trout from the Naches hatchery had a mean cholesterol value of 367 mg/dL (Table 5.7). Their mean potassium value of 8.6 meq/L also exceeded the normal range given by Wedemeyer, but was within the broader range reported by Hille (1982) (Table 5.2). All other measured blood parameters were within the expected range for healthy rainbow trout. For comparison, yearling rainbow trout from the PNL hatchery were also sampled at this time. Their mean potassium value of 1.1 meq/L was much lower than that of the Naches fish (Table 5.7).

Rainbow trout held in live boxes at the backwater pond near the Cle Elum Site had a mean potassium value of 7.5, which was outside the normal expected range reported by Wedemeyer et al. (1990), but within the range reported by Hille (1982) (Table 5.2). The mean hematocrit value of 44% also slightly exceeded the normal range reported by Wedemeyer et al. (1990), but was within the normal ranges reported by Miller et al. (1983) and Denton and Yousef (1975), i.e., 2 1% to 44% and 32% to 59%, respectively. During the second sampling at the Cle Elum Site, sodium and hematocrit values were within the normal range, but the potassium value increased to 9.3 meq/L and was higher than that of any of the other live box groups.

Table 5.5. Mean Condition Factors (CF) for Juvcnilc Rainbow Trout Hcld in Live Boxes at Various Sites in thc Yakima River Basin during 1992 (n=15)

Site	Junc 9	June 22
Clc Elum	8.8	8.2
Oak Flats	8.5	ns[(a)]
Nclson Springs	9.2	8.7
Horn Rapids	9.5	7.7
PNL hatchery	10.8	10.0

(a) ns = not samplcd.

Table 5.6. Blood Hcmatocrit and Lcucocrit Valucs for Juvcnilc Rainbow Trout Held in Live Boxes at Various Locations in the Yakima River. Valucs as mean ± S.D. and rcprcscnt 3 to 8 poolcd samples of 1 to 5 fish cach

Date	Mcan Sizc, Location	FL mm	% Hcmatocrir	% Leucocrit
5/14/92	Nachcs Hatchcty	90	42 ± 2	0.8 ± 0.4
6/9/92	Clc Elum	92	44 ± 2	1.3 fO.l
6/9/92	Horn Rapids	76	39 ± 2	0.9 ± 0.2
6/11/92	Oak Flats	92	47 ± 4	0.4 ± 0.3
6/11/92	Nclson Springs	96	42 ± 3	1.2 ± 0.2
6/15/92	PNL Hatchcry	99	42 ± 1	0.9 ± 0.5
6/22/92	Cle Elum	95	42 ± 3	1.0 ± 0.3
6/22/92	Horn Rapids	85	35 ± 2	0.8 ± 0.5
6/24/92	Nclson Springs	101	42 ± 1	1.0 ± 0.4
6/29/92	PNL Hatchcry	101	38 ± 4	0.8 ± 0.5

All blood plasma parameters for fish hcld at Oak Flats and Nclson Springs were within the normal ranges shown in Table 5.2. Thc mcan cholcstcrol valucs of thc Horn Rapids fish were lower than those of any other group, ranging from 119 to 132 mg/dL (Table 5.7), but most othcr blood parameters wcrc within the normal ranges rcportcd for rainbow trout. Watcr tcmpcraturcs as high as 25°C probably contributed to thc condition of fish hcld at thc Horn Rapids Sitc. All blood paramctcrs mcasurcd from the rcfcrcncc population hcld at thc PNL hatchcry wcrc also within thc normal ranges cxpcctcd for hcalthy rainbow trout.

The rangc of valucs for blood plasma paramctcrs of rainbow trout in 1992 was similar to those obscrvcd for fall chinook salmon in 1991, with thc cxccption of potassium, which was gcncrally higher. Again, cholcstcrol valucs appcarcd rclatcd to CF. Both thc Oak Flats and Horn Rapids fish appeared the most strcsscd, based on thc plasma paramctcrs mcasurcd. Thcsc fish wcrc noticeably thin and exposed to high watcr tcmpcraturcs during most of thc cxposurc intcrval. In contrast, fish at Nclson Springs appcarcd healthy, partly bccausc of thcir ability to exploit thc natural food sources in thc stream.

5.2 Egg Incubation Studies

Most rainbow trout cggs rcachcd thc cycd stage of dcvclopmcnt by 17 days. Hatching began 30 days after the cggs wcrc fcrtilizcd and was complctcd by day 33. Mcan time to hatching was not significantly diffcrcnt among the four groundwater sourccs or rcfcrcncc trcatmcnts. Rainbow trout rcquirc 558 tcmpcraturc units to hatch at 10°C, or approximatcly 31 days (Lcitritz and Lcwis 1980).

Table 5.7. Blood Plasma Parameters for Juvenile Rainbow Trout Held in Live Boxes at Various Locations in the Yakima River. A value sas mean ± S.D. and represent 3-8 polled samples of 1-5 fish each.

Date	Location	Glucose, mg/dL	Protein, g/dL	Cholesterol, mg/dL	Chloride, mmol/L	Calcium, mg/dL	Sodium, mmol/L	Potassium, mmol/L
5/14/92	Naches Hatchery	81 ± 6	3.4 ± 0.1	367 ± 29	129 ± 3	9.9 ± 0.4	155 ± 1	8.6 ± 1.3
6/09/92	Cle Elum	101 ± 10	3.1 ± 0.4	274 ± 71	123 ± 5	10.2 ± 1.0	148 ± 4	7.5 ± 2.3
6/11/92	Horn Rapids	91 ± 17	2.2 ± 0.4	132 ± 46	129 ± 1	9.4 ± 1.0	147 ± 1	8.4 ± 2.0
6/11/92	Oak Flats	90 ± 9	3.0 ± 0.2	247 ± 46	127 ± 2	9.8 ± 1.0	150 ± 4	7.0 ± 4.6
6/11/92	Nelson Springs	96 ± 6	2.7 ± 0.1	256 ± 34	127 ± 2	1.0 ± 1.0	150 ± 4	8.5 ± 3.2
6/15/92	PNL hatchery	94 ± 13	2.6 ± 0.2	223 ± 31	131 ± 3	10.7 ± 1.0	161 ± 3	3.5 ± 1.2
6/22/92	Cle Elum	115 ± 13	2.4 ± 0.2	173 ± 26	129 ± 4	9.2 ± 1.0	151 ± 2	9.3 ± 2.4
6/22/92	Horn Rapids	79 ± 5	1.9 ± 0.2	119 ± 23	135 ± 1	8.7 ± 1.0	151 ± 1	5.8 ± 1.4
6/24/92	Nelson Springs	107 ± 12	2.6 ± 0.2	241 ± 55	124 ± 2	10.7 ± 1.0	154 ± 2	3.9 ± 0.7
6/29/92	PNL hatchery	92 ± 8	2.7 ± 0.2	209 ± 45	129 ± 2	10.1 ± 1.0	151 ± 1	4.6 ± 0.9

Mean mortality ranged from 6.9% to 8.6% for the four treatment groups and from 7.1% to 9.2% for the reference controls (Table 5.8). The only anomaly noted with any frequency was "blue sac" disease, which contributed 38% to 54% of the post-hatching mortality. All other fish appeared healthy after hatching based on their swimming behavior and morphological characteristics. Additional information related to the experimental design and data on variability among replicate groups is in Appendix C.

At day 59 (26 to 29 days post-hatch), mean wet weights of rainbow trout fry ranged from 0.72 to 0.76 g among the four treatments and reference control populations. Mean dry weights were the same for all treatments at day 59 (Table 5.8). There was no effect of water source on wet weight, dry weight, or percentage mortality (analysis of variance, $p = 0.01$; see Appendix C).

Our results indicate that rainbow trout could be raised in the four water sources throughout their entire life cycle. Data also suggest that the four water sources would be equally suitable for other salmonids such as chinook and coho salmon.

5.3 48-Hour Screening Bioassays

Two 48-hour static bioassays were performed in the spring and summer 1991 using groundwater from test wells at Oak Flats and Prosser, and juvenile rainbow trout. No mortalities occurred for fish held in either of the groundwater sources. All fish appeared healthy following the 48-hour exposure period to the groundwater and after a subsequent 48-hour post-exposure to control water.

5.4 Conclusions

The live boxes were not an effective method of evaluating site water quality in *situ*. For example, irregular flows (i.e., floods and dewatering) and vandalism affected our ability to obtain samples from each site. A major contributing factor was the large difference in environmental conditions at each site. For example, differences of surface water temperatures of up to 18°F (10°C) were noted among sites during both years. This factor, coupled with low availability of natural food and low feeding rates with artificial diet, affected the survival and growth of different groups. Sufficient food is critical for maintaining growth and other processes. Thus, regular supplemental feeding would reduce the number of uncontrolled variables in this type of study.

The results of blood physiology monitoring were also mixed. Measures of blood electrolytes varied among exposure groups and reasons for differences were not easy to explain. Certain measures (i.e., plasma glucose and leucocrit), while indicative of acute stress (Wedemeyer et al. 1990), do not provide an adequate assessment of long-term performance. Other measures (i.e., cholesterol and total protein), change as a result of diet, season, and other environmental factors (Barnhart 1969) that we could

Table 5.8. Survival and Growth of Rainbow Trout Embryos Held in Groundwater from Five Locations in the Yakima River Basin

Treatment	Total Eggs	Number of Replicates	Mean Percent Mortality ± SD.	Mean Wet Wt(g) ± S.D.	Mean Dry Wt(g) ± S.D.
Cle Elum	781	4	6.9 ± 5.6	0.72 ± 0.03	0.12 ± 0.01
Nelson Springs	658	4	8.1 ± 6.7	0.76 ± 0.05	0.12 ± 0.01
Oak Flats	745	4	7.6 ± 5.4	0.73 ± 0.07	0.12 ± 0.02
Prosser	732	4	8.6 ± 5.9	0.75 ± 0.07	0.12 ± 0.01
PNL incubator	370	2	7.1	0.77	0.12 ± 0.01
PNL hatchery	773	4	9.2 ± 7.5	0.75 ± 0.05	0.12 ± 0.01

not control. The normal reportcd rangc of many of the blood plasma variablcs we mcasurcd was sufficiently wide and variablc that each mcasurc, vicwcd indcpcndcntly, providcd insufficicnt data to biologically scrccn watcr quality conditions. Thcsc mcasurcs may be uscful for scrccning more severe conditions, or when a suitc of mcasurcmcnts arc uscd, as in our study. Othcr strcss paramctcrs, such as blood cortisol, may havc providcd additional insight into acutc or chronic stress factors influcncing fish in thc live boxcs. Dcspitc thc limitations notcd, plasma cholcstcrol did appcar to bc a scnsitivc measure of fat storage and could be uscd for a general measure of lipid metabolism.

Thc prcscncc of low lcvcls of tracc mctals was a conccrn at scvcral of thc proposcd fish culture sites and may merit furthcr invcstigation as it rclatcs to monitoring thc performance of hatchery fish. For example, Wcdcmeycr ct al. (198 1) rcportcd that gill ATPasc cnzymc systcms of smolts and prcsmolts are sensitive to dissolvcd mctal conccntrations which arc lcss than maximum cxposurc limits recommended for freshwater growth. Thus, cxposurcs to “safc” lcvcls of mctals could actually affcct migratory behavior, osmorcgulatory pcrformancc, and ultimately thc survival of salmon and stcclhead.

The cgg incubation studics wcrc a uscful scrccn for groundwater supplics, mainly bccausc the tcsts were conductcd in thc laboratory under carcfully controllcd conditions. This approach providcd an integrative asscssmcnt of water quality conditions, had a rclativcly high precision, and would thus be uscful for scrccning watcr supplies in thc futurc. Thc mcthodology could bc adapted to in *situ* cxposurcs in surface waters, if dcsircd, in licu of thc morc complicatcd livc box studics.

6.0 Assessment of Conditions

This section provides an overall evaluation of each site based on water quality, results of our biological screening studies, and other environmental factors that may influence supplementation objectives of the YFP. Initial evaluations of potential water sources for the YFP (USBR 1990) involved a comparison of existing conditions to aquaculture criteria established for salmonids by the ADFG (1983). The ADFG aquaculture criteria are more stringent than other standards commonly reported (e.g., Piper et al. 1982; Wedemeyer 1977), including water quality standards for the State of Washington (WDOE 1988). Thus, we considered the different aquaculture criteria and water quality standards (Table 6. 1), as well as site-specific conditions, when assessing each potential water source. We also reviewed water quality conditions present in other Northwest fish hatcheries (Table 6.2) and compared the range of values present to conditions in water sources planned for the YFP. Finally, observations of fish exposed to surface water and groundwater sources for extended periods were used to determine the suitability of each site for fish production.

6.1 Cle Elum

The water quality characteristics of the Cle Elum River near the proposed facility site appear quite suitable for fish production. Surface water parameters in the Yakima River at Cle Elum are generally excellent. Although concentrations of metals in surface water sometime exceed aquaculture standards recommended by the ADFG (1983), levels are less than water quality criteria for Washington Department of Wildlife (WDW) hatcheries and also below aquaculture criteria recommended by Wedemeyer (1977). A recent concern is the potential for high concentrations of nitrogen gas to occur in the Yakima River when spilling occurs at upstream storage reservoirs.(“) These conditions should be evaluated further because spawning and incubation of spring chinook salmon populations are expected to increase as a result of supplementation practices at the Cle Elum Site.

Slightly elevated levels of aluminum, chloride, manganese, potassium, and zinc were found in groundwater sources. However, the potential for these metals to impact fish production is reduced when water hardness at the site is considered. Additionally, growth and survival of trout embryos held in groundwater from the artesian well at the site were excellent, and no disease or abnormalities were found during a 6-week exposure period. Dissolved gases in well water were sometimes high (i.e., carbon dioxide and hydrogen sulfide), but these levels can be corrected by gas stabilization practices in the hatchery design. Concentrations of dissolved gases and metals can be further reduced if groundwater supplies are mixed with surface water.

Juvenile fall chinook and rainbow trout held at Cle Elum exhibited good survival in 1991 and 1992, and there was no evidence of parasites or disease. Growth of these fish was less than that noted at other live box sites, however, but this difference was attributed to colder water temperatures and lower feeding rates of fish at this site. In the 1992 live box studies, blood plasma parameters were generally within the range expected for healthy rainbow trout.

Results of our water quality analysis and biological screening indicate that water sources at the Cle Elum Site can support both natural and artificial production of salmonids. Operations of the proposed facility are not expected to adversely impact the receiving waters downstream because water use is nonconsumptive and the low effluent volume and low water temperatures limit the potential for nutrient loading.

(a) Dr. L. Harrell, scientist, National Marine Fisheries Service; personal communication with D. D. Dauble, Pacific Northwest Laboratory, Richland, Washington, January 1994.

Table 6.1. Summary of Watcr Quality Critcria for Fish Hatchcrics (from various sources)

Chemical Name	Alaska Dept. of Fish and Game, 1983	Piper cl al., 1982	Wcdcmeyer, 1977	Water Quality Standards for Washington State-
Alkalinity	undetermined	--[a]	>20.0 mg/L	
Aluminum	<0.01 mg/L	--		0.150 mg/L
Ammonia (non ionized)	<0.0125 mg/L	<0.0125 mg/L	CO.0125mg/L	
Arsenic	<0.05 mg/L	--	--	--
Barium	<5.0 mg/L			
Cadmium (<100mg/L alk.)	0.0005	0.0004 mg/L	0.0004 mg/L	0.0011 mg/L
(>100mg/L alk.)	<0.005 mg/L	<0.003 mg/L	<0.003 mg/L	
Carbon Dioxide	<1.0 mg/L	<10 mg/L	--	
Chloride	<4.0 mg/L	--	<3.0 mg/L	
Chlorine	<0.003 mg/L	<0.03 mg/L	<0.03 mg/L	<0.019 mg/L
Chromium	<0.03 mg/L	--	--	0.016 mg/L
Copper (< 100mg/L alk.)	<0.006 mg/L	<0.006 mg/L	<0.006 mg/L	0.009 at 50 mg/L $CaCO_3$
(>100mg/L alk.)	<0.03 mg/L	--		
Dissolved oxygen	>7.0 mg/L	>5.0 mg/L		>8.0 mg/L
Fluorine	<0.5 mg/L	--		
Hydrogen sulfide	<0.003 mg/L	<0.002 mg/L	<0.002 mg/L	
Iron	<0.01 mg/L	<0.15 mg/L		
Lead	<0.02 mg/L	<0.03 mg/L	<0.03 mg/L	0.033 at 50 mg/L $CaCO_3$
Magnesium	<15 mg/L	--		
Manganese	<0.01 mg/L	<0.01 mg/L	--	
Mercury	<0.0002 mg/L	<0.002 mg/L	<0.0002 mg/L	co.0024 mg/L
Nickel	<0.01 mg/L	--		0.788 at 50 mg/L $CaCO_3$
Nitrate (NO,)	<1.0 mg/L	<3.0 mg/L	--	--
Nitrite (NO,)	<0.1 mg/L	<0.1 mg/L	<0.1 mg/L	
Nitrogen (N_2)	<110.00% total gas	<110% total gas	< 110% total gas	<110% total gas
	<103.0% nitrogen gas	--	--	
Petroleum (oil)	<0.001 mg/L	--		
pH	6.5-8.0	6.5-X.0	6.0-9.0	6.5-8.5
Potassium	5.0 mg/L	--	--	
Salinity	<5.0 parts per 1,000	--	--	
Selenium	<0.01 mg/L	--	--	0.260 mg/L
Silver	<0.003 mg/L	--	--	--
Zinc (<100mg/L alk.)	<0.005 mg/L	<0.05 mg/L	<0.03 mg/L	0.064 at 50 mg/L $CaCO_3$
(>100mg/L alk.)		--	--	
Sodium	<75 mg/L but >15 mg/L	--	--	--
Sulfate	<50 mg/L	--	--	
Temperature ("C)	o-15	O-15.5	<15.0	<18.0
Total dissolved solids	<400.0 mg/L	--		
Total suspended solids	<80.0 mg/L	<80 mg/L	<80 mg/L	
Turbidity		--		<5 NTU

(a) -- = not measured.

Table 6.2. Water Quality Characteristics from Several Washington Department of Wildlife Fish Hatcheries

Parameter (mg/L)	ADFG Standard	Spokane, 2/22/88	Lyons Ferry, 11/26/85	Lyons Ferry, 2/12/88	Omak, 10/6/89	Columbia Basin, 10/5/89	Vancouver, 4/6/77	Mossy Rock, 12/12/81
Alkalinity, $CaCO_3$	–[a]	139		140	–		96	60
Aluminum, Al	<0.01	<0.05	–		0.1	0.07	–	
Amonia, NH,-N	<0.0125	ND	0.03	–	<0.005	co.005	–	
Arsenic, As	<0.05	<0.01		–			<0.005	co.01
Barium, Ba	<5.0	<0.25	0.006				<0.02	<0.25
Cadmium, Cd	<0.005	<0.002		<0.002	<0.002	<0.002	<0.01	co.002
Carbon dioxide, CO_2	<1.0	8	–	–	–		–	
Chloride, Cl	<4.0	14	7.91	13	4.7	2.8	1.6	<5
Chlorine, Cl,	co.003	ND				–		
Chromium, Cr	<0.006	<0.01		0.005	0.027	0.022	<0.02	co.01
Copper, Cu	co.03	co.01		<0.002	co.002	<0.02	co.01	
Fluoride, F	co.05	0.5			0.6	0.36	0.06	co.02
Hydrogen sulfide, H_2S	<0.003	ND			<1.0	<1.0		
Iron, Fe	<0.01	<0.05	0.004	<0.07	<0.01	co.01	<0.05	co.05
Lead, Pb	<0.02	co.01		co.01	<0.02	<0.02	<0.005	co.01
Magnesium, Mg	<15	22.3	14.8	–	25	26	8	
Manganese, Mn	<0.01	<0.01	0.59	0.085	0.009	0.003	<0.01	co.01
Mercury, Hg	<0.0002	<0.001		<0.001	<0.0002	<0.0002	<0.0008	<0.0005
Nickel, Ni	co.01	<0.01		–				
Nitrate, NO,-N	<0.1	1.9		–	3.1	2.45		3.5
Nitrate, NO,-N	<0.1	<0.01	–		<0.001	<0.001		
pH	6.5-8.0	7.51	7.27	6.9	8.16	7.77	8.1	
Potassium	<5.0	2.65	4.48	5.6	5.1	4.5	6	
Selenium, Se	<0.01	<0.005		–		–	co.005	co.005
Silver, Ag	<0.003	<0.01		–			<0.02	co.01
Zinc, Zn	co.005	<0.01	–	<0.002	<0.002	<0.003	<0.01	
Sodium, Na	<75.0	3.8	23	26	17	14		5
Sulfate, SO,	<50.0	24.5	19.7				7.5	
Total dissolved solids	<400.0	208			454	297	–	
Turbidity, NTU		0.7		–	0.62	0.21	–	
Conductivity, µmhos.cm		–	300	349		561	414	180

(a) -- = not measured.

6.2 Nelson Springs

All water sources at the Nelson Springs Site contain some constituent concentrations that exceed aquaculture criteria. For example, slightly elevated levels of aluminum, nitrate, and zinc were found in Buckskin Creek and Nelson Springs. Concentrations of some metals (e.g., aluminum and iron) in the Naches River were also sometimes higher than aquaculture standards during the spring runoff period. However, these levels are not considered a risk to fish culture when compared to water quality data from several WDW hatcheries. Several elements (i.e., aluminum, chloride. magnesium, manganese, nitrate, and potassium) found in water sources for these operating hatcheries exceeded aquaculture standards shown in Table 6.1. Thus, constituent levels found in the Naches River and Nelson Springs do not appear to be a major concern for fish culture because many of these hatcheries have been successfully rearing salmonids for decades.[a]

Growth and survival of trout embryos in groundwater from the shallow unconfined aquifer were excellent, and no disease or abnormalities were found during a 6-week exposure period. Thus, water quality characteristics of shallow aquifers near the site appear suitable for fish culture needs. However. the 50-gpm flow rate obtained from the test well is insufficient to meet fish production needs at Nelson Springs. A pair of deep wells (>120 ft) would have to be drilled if well water is required for incubation at Nelson Springs. Sufficient water (>400 gpm) is expected to be available for full fish production but chillers would be required to lower temperatures to acceptable levels (<56°F). The high levels of zinc found in the deep golf course well are a concern, and additional water samples need to be analyzed if groundwater from a deep aquifer is used for fish culture.

Surface water sources proposed for the Nelson Springs facility have been used to raise juvenile salmonids for the past several years. The WDW currently operates a rearing pond for steelhead using water from Nelson Springs, and Naches River water is used for egg incubation and early rearing of steelhead by the WDW at an adjacent hatchery. Juvenile chinook salmon and rainbow trout had no evidence of disease and exhibited high survival and growth rates when held in the stream downstream from the confluence of Nelson Springs and Buckskin Creek. Blood plasma parameters for juvenile salmonids were within expected ranges for healthy salmon and trout during both 1991 and 1992.

Collectively, available information indicates that water quality characteristics of Buckskin Creek and Nelson Springs are suitable for fish production. Flows from these sources also appear adequate for fish culture needs. However, there is a reasonable risk of surface water quality conditions to be impacted by point or nonpoint pollutant sources in the future. This potential is based on several factors, including 1) the small size of the receiving waters to be used for hatchery operations (i.e., low dilution potential); 2) the surface water sources flowing through a large, developing residential area including a golf course; 3) both Buckskin Creek and Nelson Springs being used for irrigation and use/control conflicting with fish production; and 4) a spill several years ago that resulted in a fish kill at WDW's steelhead pond at the Nelson Springs site. These characteristics suggest a sufficient risk to production of fish at this site that an alternative source of water (i.e., from the Naches River) should be available on demand.

6.3 Oak Flats

The water quality of the surface water at Oak Flats appears quite suitable for fish production. Slightly elevated levels of zinc, iron, and aluminum were found in samples collected in 1991 and 1992, but levels do not appear to pose a risk to fish culture when other factors such as water hardness and pH are considered. The WDW successfully operates a facility used for incubation and rearing of steelhead located near Cowiche using Naches River water. Juvenile chinook salmon and rainbow trout had no

(a) Steve Roberts, Washington Department of Wildlife, personal communication with D. D. Dauble, Pacific Northwest Laboratory, Richland, Washington, August 1992.

evidence of discasc and exhibitcd good survival and growth ratcs whcn hcld in the Nachcs River near Oak Flats. Blood plasma paramctcrs for juvcnilc stcclhead wcrc within cxpcctcd rangcs for healthy trout during 1992.

Well water parameters that typically cxcecdcd aquaculturc critçria include aluminum, iron, zinc, manganese, and hydrogen sulfidc. Howcvcr, clcvatcd lcvcls of thcsc mctals do not appear to bc limiting for fish production. For example, growth and survival of trout cmbryos in groundwatcr from test wells at the site wcrc excellcnt, and no discasc or abnormalitics wcrc found during a 6-wk exposure period. Additional testing may bc rcquircd to dctcrminc hydraulic capability and water quality when ncw wells are drilled at the sitc. Gas stabilization tcchniqucs could be incorporated into groundwatcr sources to minimize the high lcvcls of hydrogcn sulfidc and othcr gases. Chillcrs would be rcquircd to cool groundwater during incubation of salmonid cggs from Novcmbcr through April.

6.4 Wapato

The ovcrall water quality at thc Wapato Sitc appcars to be conducive to acclimation of salmonids during the pcriod from March to May. Slightly clcvatcd lcvcls of zinc and aluminum occurred in surface water samples collcctcd at thc sitc. Howcvcr, thcsc lcvcls do not posc a risk to fish culturc bccausc thcy arc less than critcria cstablishcd by the Washington Dcpartmcnt of Fishcries (WDF) and others (Table 6.1). Adcquatc flow would bc availablc from the canal flow, and watcr tcmpcraturcs in the Yakima River arc within the range rccommcndcd for fish acclimation.

Good survival and growth wcrc notcd for juvenile chinook salmon and rainbow trout held in live boxes in the Wapato Canal during 1991 and 1992, and thcrc was no cvidcncc of disease or parasites. In 1991, some juvcnilc chinook salmon cxhibitcd clubbcd gills, a characteristic attributcd to chronic exposure to suspended solids during thc spring runoff period. Mcasurc of blood plasma parameters also indicated that the live box fish hcld thcrc wcrc strcsscd. Howcvcr, populations hcld in the ncarby YIN net pens did not cxhibit the same charactcristics. Subscqucnt dctailcd analysis of surface watcr conditions indicated that suspcndcd solids and turbidity wcrc within limits rccommcndcd for fish culturc. Thus, it appears that thc livc box holding conditions in thc canal (i.c., crowding) may havc contributcd to the condition of the live box fish.

6.5 Prosser

Although somc watcr quality paramctcrs (i.c., aluminum and mangancsc) cxcccd ADFG aquaculture critcria, surfacc watcr and groundwatcr sources at thc proposcd Prosscr facility appear suitable for fish production. Survival and growth of fish hcld in livc boxcs in the Chandlcr Canal were comparable to other sitcs, and thcrc was no cvidcncc of discasc or parasitcs. Thcrc wcrc no data on blood plasma parameters from thc Prosscr Sitc. In 1991, juvcnilc chinook salmon cxhibitcd clubbcd gills, a characteristic attributcd to chronic cxposurc to suspcndcd solids and turbidity during the spring runoff period. Measure of blood plasma paramctcrs also indicatcd that thc livc box fish wcrc stressed. Subsequent detailed analysis of surface watcr conditions indicatcd that suspcndcd solids were within limits recommended for fish culturc. Thus, it appcars that holding conditions in thc canal, rathcr than watcr quality, may have contributcd to thc condition of thc livc box fish.

Both surfacc watcr and groundwatcr tcmpcraturcs at Prosscr arc higher than at othcr YFP sitcs. Surface water tcmpcraturcs arc typically highcr than rccommcndcd for anadromous fish production from approximately mid-May through mid-October. Chilling of groundwater sources would also be required to reduce water tcmpcraturcs to acccptablc limits for holding adult salmon in the early fall.

6.6 Acclimation Pond Sites

Our review of available data indicates that the water quality of surface water supplies for most of the proposed acclimation pond sites is adequate for fish production. Parameters that may need further evaluation, depending on where acclimation ponds are sited, include elevated zinc concentrations in the Little Naches River and lower Toppenish Creek Sites, and potential high concentrations of iron and chloride in both the upper and lower portions of Toppenish Creek.

It is unlikely that cumulative impacts to the Yakima River ecosystem, resulting from the additive input of nutrients from acclimation pond discharges, would occur. Based on our analysis, only one upper tributary site was estimated to exceed recommended levels of nitrogen and phosphorus. Best hatchery practices, dilution of effluent by receiving waters, and the low seasonal water temperatures expected during operation of the acclimation facilities would minimize the risk of elevated nutrient concentrations downstream of the sites.

7.0 Summary and Recommendations

Our studies indicated that, with some exceptions, water quality of surfacewater and groundwater sources near proposed fish culture sites for the YFP are generally suitable for artificial fish production. However, depending on the specific stocks selected for supplementation, there are additional information needs required for natural production planning. Additionally, contingencies need to be developed for future activities that may affect the use and quality of surfacewater and groundwater supplies in the Yakima River Basin.

7.1 Summary

Current planning for the YFP (BPA 1993) includes 16 resolvable assumptions that infer knowledge of water quality conditions at the proposed supplementation facilities and other sites in the basin (Table 7.1). Although these 16 assumptions are based on four general assumptions, they differ among stocks. The assumptions, specific data needs, and recommendations for additional research are discussed below.

Facility design could proceed based on information contained in this report. Assumption numbers 9, 47, and 106 should be accepted by the YFP decision-makers as they relate to water quality for incubation and juvenile rearing at Cle Elum; juvenile rearing at Oak Flats, Nelson Springs, and Wapato; and adult holding at Prosser. However, there is sufficient uncertainty relating to use of groundwater at Oak Flats and Nelson Springs for incubation that additional studies will be required before use of groundwater at these facilities.

Table 7.1. Reference Numbers for Resolvable Assumptions Related to Water Quality at Proposed Fish Culture Sites in the Yakima River Basin. (BPA 1993).

	Chinook Salmon			Other Salmonids	
	Spring	Summer	Fall	Coho	Steelhead
Supplementation facilities can be designed and operated to reduce the possibility of extinction, loss of within-population variability, loss of between-populations variability, and domestication selection.	9	NA[(a)]	47	NA	106
An Optimum Conventional Treatment can be defined.	21	NA	60	NA	118
Physical, biological, and chemical limiting factors are well defined for all life stages so that the environment can be improved effectively (in terms of consequences and costs).	13	151	51	226	111
The natural production of the Yakima River Basin is known (for fall, spring, and summer chinook salmon, and coho salmon).	195	154	53	87	253

(a) NA = not applicable.

Assumptions 21, 60, and 118 can be accepted by decision-makers. However, it is important to note that this treatment will be different among sites, based on the range of water quality conditions known to be present at the different hatchery sites.

Assumptions 13, 15 1, 5 1, 226, and 111 can be accepted as they relate to water quality. However, sufficient uncertainty exists with respect to limitations of surface water conditions in the lower Yakima River (downstream of Prosser) on both artificial and natural production. Thus, additional data are required on these variables before operation of fish culture facilities.

Assumptions 195, 154, 53, 87, and 253 can be accepted for natural production sites upstream of Prosser. However, sufficient uncertainty exists with respect to water quality and temperature conditions present in the lower Yakima River that additional studies and monitoring are required to define the natural production potential for the basin.

Monitoring activities are recommended at the planned supplementation facilities to ensure that fish culture and monitoring activities are conducted as intended and to reduce to a minimum the variation from sources other than experimental treatments. Monitoring is required during operation of fish culture facilities to provide information on the range of conditions present and to identify contingencies (i.e., filters, chillers). Additionally, hatchery operators should measure major water quality parameters, in conjunction with performance measures of fish, during future culture activities planned for the basin. Additional information on water quality and temperatures is important to ensure that performance (product definition) of artificially and naturally reared fish can be compared. These performance measures may include blood plasma parameters, in addition to disease, survival, and growth. Release timing, based on optimum temperature or other water quality conditions present, is also a consideration relative to risk containment.

7.2 Recommendations

Specific recommendations related to current planning of fish production facilities in the Yakima River basin include the following:

- Planners should include an option for pumping water from the Naches River "on demand" for fish production activities that require the use of surface water from Buckskin Creek or Nelson Springs. This is needed because of the potential for acute and chronic contamination of Nelson Springs and Buckskin Creek from domestic development activities that occur upstream of the proposed hatchery site.

- Additional assessment of groundwater from deep wells, if any, from the Nelson Springs site is needed before their use for fish culture.

- Additional testing is required to evaluate groundwater supplies at Oak Flats if future wells are developed at the site.

- Gas stabilization techniques should be used to reduce dissolved gas concentrations at all sites using groundwater for fish culture.

- Planners should explore the potential for mixing water supplies (i.e., relative volumes of surfacewater and groundwater) to reduce seasonally high concentrations of metals that sometimes occur during the spring runoff.

- Investigations should be conducted to evaluate the potential for gas supersaturation to impact surface water in the Yakima River downstream of Keechulus Dam.

- Chillers are needed to cool groundwater used for incubation at Cle Elum, Oak Flats, Nelson Springs, and Prosser.

- Seasonal use of chillers may be needed to cool surface water supplies used for adult holding at Prosser.

- Water quality procedures, including methodology, frequency, and contingencies, need to be included in the operations manuals for all facilities.

Specific recommendations related to strategies for natural production of satmonids in the basin include the following:

- Technical teams should develop and maintain a temperature monitoring network in cooperation with other resource agencies (e.g., USBR, USFS) in the Yakima River Basin.

- Project planners should assess water quality conditions for new groundwater sources that may be developed and at surface water sites where acclimation ponds may be constructed.

- Project planners should conduct further investigations of water quality at lower Yakima River acclimation sites.

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Appendix A

Temperature and Flow Data Summary

Appendix A

Temperature and Flow Data Summary

This appendix includes a list of sites in the Yakima River Basin where temperature and flow measurements have been taken, period of record, methods used, agency or organization involved, and the format of the data (i.e., electronic or printed). Citations have been provided for all published data and procedures described for accessing electronic data files. Additionally, a synopsis of major reports and other articles on temperature and flow is included.

Water Temperature and Flow Database Summary for the Yakima River Basin

Introduction

The ability of the Yakima Fisheries Project to increase anadromous fish production through supplementation will be based in large part by the availability of adequate water flow and optimum water temperature conditions. Fishery managers and technical teams will need access to this information for production planning.

This appendix summarizes the temperature and flow database within the Yakima River Basin through calendar year 1992. It provides a listing of agencies who have and are in the process of collecting data within the basin, a listing of sampling stations, and period of record for the data. In addition, the method of retrieval, format of data, and procedures to access the data are described.

Earliest reported stream flow data began in 1897 in the Yakima River near Selah. Several gauging stations located on irrigation canals came with construction of irrigation canals in the early 1900s (Rinella et al. 1992). Much of the early data collection was conducted primarily by the U.S. Bureau of Reclamation (USBR), the U.S. Geological Survey (USGS), and Washington Department of Ecology (Ecology). These three agencies store data into the U.S. Environmental Protection Agency's (EPA) STOrage and RETrieval Computer System (STORET) as well as their own databases. Types of measurements (i.e., daily, monthly, yearly) varied depending on the agency collecting the data and the location within the basin.

The USGS historically operated a network of 140 water quality sampling sites throughout the basin. Other sources of flow and temperature data from the Yakima River Basin include the U.S. Forest Service (USFS), CH_2M Hill, EPA, Ecology, Yakama Indian Nation (YIN), and Pacific Northwest Laboratory (PNL).

Database Systems

Existing databases for flow and temperature in the Yakima River Basin are described in this section.

USBR Hydromet System

The USBR has been collecting temperature and flow data throughout the Yakima River Basin since the early 1900s. The USBR Yakima office contains a library of early 1900s flow and temperature data. The remaining data have been incorporated into the Hydromet database. The Hydromet system currently collects discharge and temperature data along with other parameters. Depending on the site and time of year, water temperature and discharge readings are taken at various time intervals during a 24-hour period. Temperature and flow parameters are sent via a network of satellites to a central VAX computer network at the USBR offices in Yakima. Data are available to agencies via computer modem. Each server can determine what information is needed then a custom menu can be generated from the main VAX. Users may log onto the system at any time after providing a password and user name. Files may then be downloaded to users and viewed on a computer monitor.

Depending on the station, flow and temperature data are sent as dayfiles at intervals ranging from 15 minutes to 2 hours. From there the data are relayed via satellite to the Hydromet system as dayfiles, usually five times per 24-hour period. These preliminary files are not verified until they are screened and placed into the archive database. The data are corrected if an error in collection is detected from a particular site.

Table A. 1 shows a listing of Hydromet sites and dates temperature and flow data are available from the system (excluding reservoir sites). There are currently 46 sites in the Hydromet system in the Yakima River Basin. Each site has a three or four letter code that is used to identify each site. Not all sites have the ability to collect flow and temperature data. Depending on the need for such ability the USBR can determine what parameters need to be collected. Hydromet sites consist of the following three categories 1) mainstem Yakima River, 2) main tributaries, and 3) canal flows.

USGS WATSTORE System

This application contains water quality data on a series of CD-ROM disks. The USGS opened the National WATer Data STOrage and Retrieval System (WATSTORE) system for direct public access in 1976. The system may be accessed by synchronous or asynchronous methods. Beginning in 1990, all water data reports were available on CD-ROM for a fee (Miles et al. 1992).

The USGS has a major role in assessing the quality and quantity of the nation's waterways. The organization provides state, federal, tribal, and local agencies with information that is used by managers and policy makers. Much of the data goes into the USGS's National Water Quality Assessment (NAWQA) Program. The national program was initiated in 1986 and its goals are to provide a sound understanding of natural and human factors that affect water quality, and define water quality trends that have occurred over the recent decades (Rinella et al. 1992).

The USGS currently operates approximately 140 sampling sites in the Yakima River Basin. These stations are identified by an eight-number survey site code in the WATSTORE database (Table A.2). Discharge and water temperature summaries as well as other water quality parameters are published in annual water data reports and open-file reports available from the USGS.

EarthInfo Inc. CD-ROM

The company provides digitized hydrological and water quality data contained in the USGS WATSTORE files. Data are available in the form of CD-ROM disks that contain USGS daily values, peak values, and quality of water. The disks can be purchased or leased from the company. Updated versions can be acquired by-yearly. The system has built-in software programs that allow the user to manipulate the data into graphic and table formats depending on what parameter is selected. Costs for the disks range from $500 to $1,200 depending on the purchase or leasing of disks. The company also acquired the STORET database available on CD-ROM for Washington and Oregon in December 1993.

EPA STORET Database

STORET is administered by the Office of Wetlands, Oceans, and Watersheds in conjunction with the Office of Information Resources Management. The database contains over 150 million separate chemical and physical parameters at over 730,000 stations in the U.S. The sites include freshwater, marine environments, and groundwater. The data submitted to the STORET database originates from various sources including state, EPA, and other federal agencies, engineering firms, private institutions, and universities. In addition, data from the USGS WATSTORE database are transferred to STORET at regular intervals. Over 13,000 different parameters divided into 18 groups are contained in the database. The IBM-based database can be accessed via computer modem by government agencies by contacting EPA in Seattle. Consulting firms and other agencies can also gain access to the data by using the Freedom of Information Act. A minimum fee is required for menu setup by EPA personnel. Hard copy files are available at 0.15 cents per page. The user can use specific commands to access water quality data from over 300 sites throughout the Yakima River Basin. Because STORET contains data from many agencies, the user must obtain the station numbers, desired sample dates, and stream segments or geographical area where the sites are located. A sample of a summary report for a particular site would include the station name and site code, number of values taken, sampling period, mean, median, and max/min values.

Table A.1. Historical Hydromet Data

Location	Site Code	Temp. Dates	Flow Dates
Yakima R. at Kiona	KIOW	NA	1933 - Present
Yak. R. below Prosser Dam	YRPW	1987 - Present	1985 - Present
Yak. R. at Prosser forebay	PRO	1980 - 1992	1981 - Present
Yak. R. at Grandview	YGVW	NA	1984 - Present
Sulphur Creek Wasteway	SUCW	NA	1984 - Present
Yak. R. Sunnyside Diversion	SNCW	NA	NA
Yak. R. at Terrace Heights	YRTW	NA	1982 - Present
Yak. R. below Roza Dam	RBDW	NA	1986 - Present
Roza Diversion at Dam	Rzcw	1988 - Present	NA
Yak. R. at Umtanum	UMTW	1988 - Present	1931 - Present
Wilson Cr. near Thrall	WONW	NA	1984 - Present
Yak. R. at Ellensburg	ELNW	1987 - Present	1939 - Present
Tcanaway R. at forks	TNAW	NA	1966-67, 1971 - Present
Yak. R. at Cle Elum	YUMW	1988 - Present	1909 - Present
Yak. R. at Easton	EASW	NA	1941 - Present
Naches R. near Yakima	NRYW	1987 - Present	1981 -Present
Naches R. near Naches	NACW	1988 - Present	1909 - Present
Naches R. at Oak Flats	NOFW	1991 - Present	NA
Naches R. near Cliffdell	CLFW	1992 - Present	1977 - Present
Naches River near Yakima	NRYW	1987 - Present	1981 -Present
Yakima R. at Parker	PARW	1987 - Present	1908 - Present

Other Data Sets

The USFS collects stream temperatures in the Wenatchee National Forest. The Naches Ranger Station currently collects temperature data from 74 sites in their district. Maximum and minimum temperature values are recorded during the late summer early fall period on many small creeks and streams within the national forest. This information is available from hydrologists with the USFS. CH_2M Hill and PNL have collected limited water temperature data in 1990 through 1992. Additional temperature data were collected at various locations downstream from Prosser by the Yakama Indian Nation during the summer of 1992. A listing of these collection periods is presented in Table A.3.

Table A.2, USGS WATSTORE Temperature and Discharge Record
(partial listing from Miles et al. 1992)

Location	Station Number	Temperature	Discharge
Yakima R. at Union Gap	12503000	3/1981 - 12/1981 1980 - 1985	10/1898 - 9/1966
Yakima R. near Martin	12474500	4/1981 - 4/1982	2/1904 - 9/1978
Yakima R. near Easton	12477000	1981 - 1982	1904 - 05; 1910 - 15 1944 - 50; 1950 - 55
Yakima R. at Cle Elum	12480600	10/1907 - 9/77;5/1981 - 1 1/81	10/1906 - 3/1990
Yakima R. at Umtanum	12484500		10/1908 - 12/1991 (f)
Yakima R. at Roza Dam	12484900	10/1965 - 12/1970	
Yakima R. at Selah Gap	12487000		5/1897 - 1912 (f)
Yakima R. near Parker	12505000	10/1959 - 12/1970	5/1908 - 9/1978
Yakima R. at Mabton	12508990	3/1981 - 2/1982	10/1970 -11/1991
Yakima R. near Prosser	12509500	6/1905 - 9/1923	1904 - 06; 1913 - 33
Yakima R. near Richland	12512000		8/1910 - 9/1911
Yakima R. near Thorpe	12482600	10/1974 - 9/1975	
Yakima R. above Cle Elum	12477600	1972; 1975	
Yakima R. at Kiona	12510500	1956 - 57;10/78 - 9/1979 12/1952 - 9/1978	10/1905 - 1 1/1991
Yakima R. at Grandview	12509050		1987-90
Naches River at Oak Flats	12489500		1904 - 18
Naches River near Naches	12494000		1905; 1908 - 79
Naches River below Tieton	12494000		1909-79
Tieton R. near Naches	12492500	4/1981 - 10/1981	
Ahtanum C. at Union Gap	12502500	3/1981 -12/1981	
Satus Creek at Satus	12507660	3/1981 - 2/1982	
Teanaway R. near Forks	12478900		1968-73
Taneum Cr. near Thorp	12482000		1911-12
Cle Elum R. near Roslyn	12479000		1904 - 78
Wilson Cr. near Ellensburg	12483600		1909-14
Toppenish Cr. near Ft. Simcoe	12506000		1909-24

(f) = fragmented data

Table A.3. Temperature and Flow Records from Selected Sources

Source	Location	Temperature	Discharge
DOE/USGS	Yakima R. at Kiona	1953 - 1991	1953 - 1991
	Yakima R. at Cle Elum	4/14/87 - 2/20/91	4/14/87 - 3/13/90
	Naches R. at Yakima	4/15/87 - 3/14/90	4/15/87 - 3/14/90
	Yakima R. at Union Gap	8/15/86 - 7/8/91	8/15/86 - 9/17/90
	Yakima R. at Kiona	9/15/86 - 8/6/91	9/15/86 - 10/19/90
CH_2M Hill	Nelson Springs	1990	
	Buckskin Creek	1990	
	Naches R. at Cowiche	some 1990	
	Naches R. at Oak Flats	1990	
	Yakima R. at Cle Elum	1990	
	Wapato Canal	some 1990	
	Chandler Canal	1990	
	Yakima R. at Prosser	some 1990	
PNL	Yakima R. at Cle Elum	4/18/91 - 6/20/91	
	Naches R. at Oak Flats	4/18/91 - 6/20/91	
	Nelson Springs	4/18/91 - 6/20/91	
	Buckskin Creek	some 1991	
	Chandler Canal	4/18/91 - 6/20/91	
	Wapato Canal	4/18/91 - 6/20/91	
	Toppenish Creek	summer 1992	
	Yakima R. at Horn Rapids	summer 1992	
Yakima Indian Nation	Yakima R. at Van Giesen	6/18/92 - 11/30/92	
	Yakima R. at Horn Rapids	7/8/92 - 11/30/92	
	Yakima R. at Vantage Highway	6/27/92 - 11/30/92	
	Yakima R. near Chandler Power Plant	6/27/92 - 11/30/92	
	Yakima R. above Granger	6/20/92 - 11/30/92	
	Chandler Trap	6/27/92 - 11/30/92	
	Benton City Bridge	6/27/92 - 11/30/92	
	Marion Drain	6/20/92 - 11/30/92	
	Granger Drain	6/20/92 - 11/30/92	

References

CH_2M Hill. 1977. A Status Report on Water Quality Investigations Yakima River Basin Washington. Yakima Valley Water Management Study for US Bureau of Reclamation. U.S. Bureau of Reclamation # 14-05-100-9158.

McKenzie, S.W. and J.F. Rinella. 1987. Surface-Water-Quality Assessment of the Yakima River Basin, Washington: Project Description. U.S Geological Survey Open-File Report 87-238. Tacoma, Washington.

Miles M.B., W.D. Wiggins, G.P. Ruppert, R.R. Smith, L.L. Reed, and L.E. Hubbard. 1992. Water Resources Data Washington Water Year 1992. U.S. Geological Survey Water-Data Report WA-92-l.

Molenaar, D. 1985. Water in the Lower Yakima River Basin, Washington. Water-Supply Bulletin 53. State of Washington, Department of Ecology. Prepared in Cooperation with the U.S. Geological Survey.

Molenaar, D. 1985. Water in the Lower Yakima River Basin, Washington. Washington State Department of Ecology , USGS Water Bulletin 53, 159 pp.

Pearson, H.E. 1985. Hydrology of the Upper Yakima River Basin, Washington. Washington Department of Ecology. USGS Water Supply Bulletin 52. 220 pp.

Rinella, J.F., S.W. McKenzie, and G.J. Fuhrer 1992. Surface Water Quality Assessment of the Yakima River Basin, Washington: Analysis of Available Water Quality Data through 1985 Water Year. USGS open file report 91-453, Portland Oregon.

McKenzie, S.W. and J.F. Rinella. 1987. Surface-Water-Quality Assessment of the Yakima River Basin, Washington: Project Description. U.S Geological Survey Open-File Report 87-238. Tacoma, Washington.

Sylvester, R.O. and Seabloom, R.W. 1962. A Study on the Character and Significance of Irrigation Return Flows in the Yakima River Basin. University of Washington, Department of Civil Engineering, Seattle, Washington.

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Vaccaro, J.J. 1986. Simulation of Streamflow Temperatures in the Yakima River Basin, Washington, April-October 1981, U.S. Geological Survey Water Resources Investigations Report 85-4232. Tacoma, Washington Prepared in Cooperation with the Yakima Indian Nation.

Vaccaro, J.J. 1986. Comparison of Unregulated and Regulated Streamflow for the Yakima River at Union Gap and near Parker, Washington, U.S. Geological Survey Water Resources Investigations Report 82-646. Tacoma, Washington. Prepared in Cooperation with the Yakima Tribal Council.

Addresses of Principal Agencies with Flow and Temperature Data for the Yakima River Basin

Books and Open-File Rcports Scclion
U.S. Gcological Survey
Federal Center
Box 25425
Denver, Colorado 80225
303-236-7476

U.S. Bureau of Reclamation
Yakima Project Office
1917 Marsh Road
P.O. Box 1749
Yakima, Washington 98907-1749
509- 575-5848

EarthInfo Inc.
5541 Central Avenue
Boulder, Colorado 8030 1
303-938-1788

U.S. Forest Scrvice
Wenatchee National Forcst
Nachcs Rangcr District
10061 Highway 12
Naches, WA 98937
509-653-2205

U.S. Environmcntal Protection Agcncy (STORET)
Region 10 Watcr Division
1200 Sixth Avenue
Seattle, WA 98101
206-553-2987

U.S. Geological Survcy
10615 S.E. Cherry Blossom Drive
Portland, Orcgon 97216

U.S. Gcological Survcy
Water Rcsourccs Division
403 West Lewis
Pasco, WA 99301
509-547-2571

Literature Synopsis For Temperature And Flow References

CH_2M Hill. 1977. *"A Status Report on Water Quality Investigations, Yakima River Basin, Washington".* Yakima Valley Water Management Study for U.S. Bureau of Rcclamation. U.S. Bureau of Reclamation #14-05-100-9158. 113 pp.

Water quality and the effects of storage, diversion, rcturn flows, runoff, and erosion are reported. Thc headwaters of the Yakima River exhibit excellent watcr quality parametcrs. Howcver, water quality is affected when the first major irrigation return flows enter thc river from the Kittitas Valley at Wilson Creek. Furthcr degradation occurs from the Ahtanum and Moxee Valleys duc to the addition of muni - cipal and industrial wastewaters. Between the Sunnyside Dam and Mabton, summcr flows are significantly reduced by diversion, thcrc is less gradient, watcr tcmpcraturcs rise, and nutricnt- and sedimentrich return flows producc river water that cannot mcct evcn thc lowest water quality standards.

Water quality data have cstablishcd that small increases in water temperature and small decreases in dissolved oxygen occur as a result of rcscrvoir storage. Howcvcr, data also indicate that water in the storage reservoirs is of cxccllcnt quality for most uscs, and can bc uscd cffcctivcly to mitigate irrigation return flows. Multiple-lcvcl watcr outlct systems arc bcing constructcd in ncwer dams to allow flexibility in operation and in thc quality control of thc dischargc, whcrcas Yakima River dams do not have facilities for drawing watcr at diffcrcnt lcvcls.

McKenzie, S.W., and J.F. Rinclla. 1987. *"Surface-Water-Quality Assessment of the Yakima River Basin, Washington: Project Description".* U.S. Gcological Survcy Opcn-Filc Rcport 87- 238. Tacoma, Washington. 35 pp.

In 1986, the U.S. Gcological Survcy cstablishcd thc National Water Quality Asscssmcnt program to provide a national procedurc to dcscribc watcr quality conditions, dcfinc historical watcr quality trcnds, and relate past and prcscnt watcr quality conditions to natural fcaturcs, land and watcr use history, and land and waste managcmcnt practiccs. Thc Yakima Rivcr Basin Water Quality Assessment Projcct, one of thc pilot surface watcr projcct arcas, is cxamincd in this rcport. Thc hydrology of thc Yakima River Basin and the cffccts of land-use activitics, including timbcr harvcsting, pasture grazing, farming, and irrigated agriculture and thcir impact on watcr quality (suspcndcd scdimcnt, turbidity, nutricnts, bacteria, pesticides, tracc clcmcnts, etc.) arc asscssed.

The effects of six storagc rcscrvoirs, 14 major divcrsions on the main stcm, 1900 miles of canals and laterals, hydroclcctric plants, and irrigation projects on the watcr quality of the rivcr are addressed in this report, as wcll as thc cffccts on fishcrics.

Prcvious Yakima River watcr quality studies arc prcscntcd in synopsis form and proposed sampling and intensive rcach studies arc dciincd.

Milcs, M.B., W.D. Wiggins, G.P. Ruppcrt, R.R. Smith, L.L. Rccd, and L.E. Hubbard. 1992. *"Water Resources Data, Washington Water Year* 1992". U.S. Gcological Survcy Watcr-Data Rcpott WA-92- 1. 461 pp.

Water rcsourccs data for thc 1992 watcr ycar for Washington, including the Yakima Rivcr basin, are prescntcd. Data includcs rccords of stagc, dischargc, and strcam watcr quality; stage, contcnts, and water quality of lakcs and rcscrvoirs; and watcr lcvcls of wells. Dischargc rccords for 220 stream-gaging stations, 85 partial-record or misccllancous strcamllow stations, and 22 crcst-stagc, partial record streamflow stations arc includcd, as wcll as stage records for 4 gaging stations, stage and/or content records for 33 lakcs and reservoirs, and watcr quality rccords for 29 strcamflow gaging stations and 7 ungaged streamsitcs.

Water discharge records (daily mean values) for ten sites in the Yakima River basin are reported, as well as water quality records for two sites: Kiona, Washington, and Union Gap, Washington. Water quality parameters examined include: specific conductance, pH, temperature, turbidity, dissolved oxygen, hardness, colifonn, calcium, magnesium, sodium, potassium, alkalinity, bicarbonate, carbonate, sulfate, chloride, fluoride, silica, solids, nitrogen, phosphorus, aluminum, barium, cobalt, iron, lithium, manganese, molybdenum, nickel, selenium, silver, strontium, vanadium, and sediment.

Molenaar, D. 1985. *"Water in the Lower Yakima River Basin, Washington."* Water Supply Bulletin 53. Prepared in cooperation with the U.S. Geological Survey. Washington State Department of Ecology. 159 pp.

This report presents a compilation and interpretation of hydrologic data for the Lower Yakima River Basin. Water years 1960-1977 are examined, as well as some later data through 1979. Data include precipitation records; water storage in lakes and reservoirs; discharges of streams, canals, drains and their related water quality; well records, and groundwater quality. Irrigation and municipal and industrial water usage is also addressed.

Water quality data includes chemical constituents, specific conductance pH, temperature, suspended sediment, pesticides, and microbiological data.

Pearson, H.E. 1985. *"Hydrology of the Upper Yakima River Basin, Washington."* Washington Department of Ecology. U.S. Geological Survey Water Supply Bulletin 52. 220 pp.

This report summarizes available surface and groundwater data in an effort to present the hydrologic conditions of the Upper Yakima River. Surface water data includes snowfall data, glacier inventory, major reservoir storage, stream discharges, and analysis of the chemical, physical, and sanitary quality of the water. Groundwater data includes well records, records of materials penetrated during drilling, well water levels, and water quality analyses. Data on water used for irrigation, municipal, industrial, and domestic supplies is also presented.

Water quality data includes chemical constituents, water temperature, and suspended sediment. The effects of floods and low flows are also addressed.

Rinella, J.F., S.W. McKenzie, and G.J. Fuhrer. 1992. *"Surface Water Quality Assessment of the Yakima River Basin, Washington":* Analysis of Available Water Quality Data through 1985 Water Year. U.S. Geological Survey open file report 9 l-453. Portland, Oregon. 244 pp.

The historical water quality conditions of the Yakima River Basin, including long- term trends in water quality and relations of the historical conditions and trends with natural and human factors, were reported. Water quality in the Lower Yakima was determined by agricultural rctum flow, as up to 80 percent of the lower main stem flow during irrigation season is attributed to return flows. Monthly water quality data from 1974-198 1 indicated increases in stream temperature, specific conductance, and concentrations of orthophosphate, ammonia, and nitrate/nitrite were widespread in the basin during these water years . Up to fifty percent of the increased specific conductance was attributed to decreasing streamflows, and increased ammonia, nitrate/nit&c and organophosphate concentrations were attributed to nitrogen and phosphorus fertilizers and increased livestock populations. Turbidity and suspended sediment quantities in the upper Yakima River were generally at low levels, but nearly double those downstream at Terrace Heights Bridge, due to agricultural rctum flows during irrigation season. Concentrations of suspended sediment were highest at the Sunnyside subbasin, due to erosion of the steep slopes. Increased stream turbidity may limit aquatic plant growth and cause eutrophic conditions.

Stream temperature measurcments from 400 sites from thc 1959 to 1985 water years indicated that Washington State standards were somctimes excecdcd during the summer months duc to high air tern - peratures and low stream flows. Nutricnt enrichment during the summcr months often resulted in scattered patches of dcnsc attachcd and rooted plant growth in thc slow-moving rcachcs of the Yakima downstream from its confluence with Satus Creek.

Fish and aquatic biological communities of thc Yakima Rivcr wcrc also examincd. Results indicated that the following factors affcct fishery habitat: passage problems due to irrigation diversions in thc tributaries; low streamflows and flow fluctuations advcrscly affccting passagc, spawning, and rearing; erosion of agricultural soils and subsequcnt sediment dcposition into thc fall chinook spawning beds on the lower river; false-attraction flows associatcd with agricultural rctum flows; lack of large organic debris caused by high- flow augmentation for irrigation; high strcam tcmperatures in thc lowcr river causing a partial thcrmal block for fish passage and a dccreascd habitat for native, cold water species; pesticide levels abovc safc, chronic cxposurc levels for fish in the main stcm and in agricultural returnflows; and degradation of riparian cover due to grazing and agriculture. Bcnthic invcrtcbratc and phytoplankton were also advcrscly affcctcd by watcr quality conditions along thc main stem of the Yakima River due to scdimcnt dcposition, turbidity, tcmpcraturc, and high organic-carbon concentrations.

Sylvester, R.O., and R.W. Scabloon. 1962. *"A Study on the Character and Significance of Irrigation Return Flows in the Yakima River Basin".* Univcrsity of Washington, Dcpartmcnt of Civil Engineering. Seattle, Washington. 104 pp.

The cffccts of rctum flows on water quality during a 1959-60 study arc prcscntcd in this report. Forty-seven sampling sites wcrc cstablishcd throughout thc Yakima Vallcy and watcr quality parameters mcasurcd includcd temperature, flow, dissolvcd oxygcn, pH, alkalinity, hardness, turbidity, color, conductivity, chlorides, nitratc, total Kjcldahl nitrogcn, chcmical oxygcn dcmand, soluble and total phosphate, sulfate, calcium, magncsium, sodium, potassium, and coliform bactcria. Rcturn flows and how thcy are impactcd by cvapo-transpiration, lcaching, ion cxchangc, liltration, fcrtilization, crop removal, crosion, and cncrgy transfcr wcrc addrcsscd.

Irrigation return flows wcrc found to havc a major impact on overall watcr quality as compared to domestic scwagc and industrial waste dischargcs. Incrcascd salt composition in thc return flow watcr was attributed to lcaching and ion cxchangc. During irrigation scason, watcr tempcraturc incrcascd by an average of 4.3 dcgrccs Ccntigradc bctwccn thc point of application and whcrc it was discharged into the main river (whcn rctumcd to the river via surface routcs), whilc subsurfacc sccpagc and drainage from irrigated ficlds was an avcragc of 2.7 dcgrccs Ccntigadc lowcr than thc applicd watcr. Color and turbidity of the Yakima Rivcr wcrc incrcascd morc by natural runoff than by irrigation flows, except during summer months. Irrigation canals and latcrals causcd incrcascs in watcr tcmpcraturc, color, and turbidity. Studies conductcd on thc lower 72- milcs of thc Yakima indicatc that the watcr tempcraturc of thc Yakima River was incrcascd by at lcast 4 dcgrccs Ccntigradc duc to irrigation rctum flows.

U.S. Bureau of Reclamation. *1990. "Yakima/Klickitat Production Project Preliminary Design Report, Appendix B".* Bureau of Rcclamation. Boise, Idaho. 246 pp.

This rcport prcscnts a water supply analysis conductcd by thc Bureau of Rcclamation, under an interagency agrccmcnt with thc Bonncvillc Powcr Administration, on thc Yakima/Klickitat Production Projcct. Thc quality and quantity of watcr supplics wcrc cvaluatcd, including their adcquacy for anadromous fish spawning, incubation, rcaring, and migration both prior to and aftcr completion of the proposed production facilitics. Existing constraints to achicving anadromous fish production potcntials in both the Yakima and Klickitat basins wcrc addrcsscd, as wcll as currcnt favorablc habitats in thc basins.

Flow data was cxamincd to dctcrminc whcthcr surface watcr quantitics cxist to mcct thc projcctcd nccds of proposcd facilities. Surface watcr quality was asscsscd by cxamining parameters including water temperature; chemical constituents including aluminum, manganese, sodium, chloride, nitrates, zinc, chromium, iron; dissolved gases: and pesticides. Groundwater quantities were determined using pump tests of exploration wells in an effort to assess whether they would meet the projected needs of proposed facilities. Quality of the groundwater, including temperature, chemical constituents, and dissolved gases was measured to determine the suitability for use for fish culture.

Vaccaro, J.J. 1986. *"Comparison of Unregulated and Regulated Streamflow for the Yakima River at Union Gap and Near Parker, Washington."* Prepared in cooperation with the Yakima Tribal Council. U.S. Geological Survey Water Resources Investigations Report 82-646. T acoma, Washington. 54 pp.

The effects of reservoir storage and canal diversion on the Yakima River streamflow at Union Gap and near Parker, Washington, were determined using average discharge records for water years 1926 through 1977, at 13 stream gaging stations. Adjustments for changes in storage contents in five reservoirs and flow diversions to 58 canals were made using the Streamflow Synthesis and Reservoir Regulation (SSARR) numerical streamflow-routing model. The effects of regulation on the Yakima River were assessed utilizing annual means, monthly means, and annual minimum 7-day and 183-day averages of the computed unregulated and recorded regulated daily mean discharges.

Regulation was determined to have reduced the unregulated 52-year mean-annual discharge at Union Gap and Parker due primarily to agricultural irrigation and the export of water from the Upper Yakima basin to the Lower Yakima basin. Springtime high flows have been reduced at both locations, but August-September low flows at Union Gap have increased. Summer flows near Parker are drastically reduced due to the Sunnyside Canal, and the New and Old Reservation Canals. Regulation has reduced the standard deviations of the monthly and annual mean discharges at Union Gap and near Parker, and has increased variation coefficients for the monthly and annual mean discharges near Parker, and the winter-spring monthly mean discharges at Union Gap.

Vaccaro, J.J. *1986. "Simulation of Streamflow Temperatures in the Yakima River Basin, Washington, April-October 1981."* Prepared in cooperation with the Yakima Indian Nation. U.S. Geological Survey Water Resources Investigations Report 85-4232. Tacoma, Washington. 91 pp.

The effects of four alternative management scenarios: storage, diversion, return flow, and meteorological variables on water temperature were simulated and evaluated as to the effects on anadromous fish populations. A streamflow routing model and Lagrangian streamflow temperature model were used to simulate water discharge and river temperature.

The effects of reservoir outflow on river temperature was found to diminish with distance in a downstream direction. The influence of air temperature on water temperature increased with downstream distance and was found to be the dominant influence on the lower river basin.

The most advantageous alternative management scenario evaluated was found to be reservoir releases maintained without diversions or return flow in the river basin. This alternative produced water temperatures nearest those considered as preferable to the salmon and steelhead trout habitat. The alternative nearest to that of natural conditions (i.e., no reservoir storage and no diversions or return flows in the river basin) produced conditions that were least like those considered preferable for anadromous fish habitat. This scenario was least effective for increasing streamflow and decreasing water temperatures in the river basin.

Appendix B

Water Quality Data

Appendix B

Water Quality Data

This appendix contains more detailed water quality data collected from surface water and groundwater sources.

Table B.l. Water Quality Parameters Measured at Cle Elum at Well CE-PW-2

Parameter	2/12	2/28/92	3/13/92	3/19/92	4/2/92
Al	0.043	0.041	0.032	0.034	0.034
Alkalinity	141.7	135	143	135	141
Ca	29.909	29.404	29.599	29.334	28.819
c l	-	7.55	7.28	6.98	7.10
Cr	0.005	<0.0035	<0.0035	<0.0035	0.003
Cu	<0.0018	<0.0020	<0.0020	<0.0020	<0.0013
Fe	0.013	0.011	0.018	0.026	0.020
Hardness	265	150	152	144	152
K	0.628	0.68	0.632	0.633	0.567
Mg	15.697	15.501	15.782	14.713	14.938
Mn	0.046	0.050	0.05 1	0.047	0.052
Na	5.257	5.825	5.872	5.45	5.49
NO_3	0.53		0.00	0.00	0.07
PH	8.44	8.40	8.26	8.25	7.99
SO4		11.9	11.27	11.28	10.27
Zn	0.039	0.007	0.006	0.002	<0.0013

Table B.2. Water Quality Parameters Measured in the Bonneville Power Administration Trailer Well at Nelson Springs

Parameter	2/12/92	2/28/92	3/12	3/12	4/2/92	3/26/92
Al	0.026	0.025	0.018	0.021	0.024	0.052
Alkalinity	67.4	65	71	64	70	
Ca	15.215	15.567	14.945	15.062	15.037	39.754
c l	0.10	0.13	4.24	4.40	4.70	9.16
Cr	0.003	<0.0035	<0.0035	0.004	0.003	0.004
Cu	<0.0018	<0.0020	<0.0020	0.005	<0.0013	<0.0020
Fe	0.008	0.014	0.009	<0.0057	0.017	co.0057
Hardness	77	64	64	63	67	
K	2.441	2.406	2.399	2.413	2.287	6.582
Mg	4.997	5.018	4.997	4.926	5.003	17.362
Mn	<0.0003	0.001	0.001	0.001	0.001	0.016
Na	8.142	8.737	8.048	8.15	7.741	15.484
NO_3	4.11	4.13	0.12	3.48	0.12	4.28
PH	8.57	8.2	7.93	7.86	7.63	
SO_4	0.00	7.28	6.96	6.98	7.09	27.38
z n	0.019	0.016	0.016	0.020	0.017	0.073

Table B.3. Water Quality Paramcters Measured at Oak Flats Well OF-l

Parameter	8/6/9_	2/12	2/28/92	3/13/92	3/19/92	4/2/92
Al	0.0135	0.02	0.019	0.014	0.015	0.014
Alkalinity	87.9	85	92	85	135	89
Ca		9.05 1	9.641	9.736	9.587	10.009
c l		0.48	7.26	0.48	7.76	7.67
Cr	<0.0044	0.005	co.0035	co.0035	<0.0035	0.007
Cu	co.002 1	<0.0018	<0.0020	<0.0020	<0.0020	co.0013
Fe	0.0104	0.02 1	0.016	0.018	co.0057	0.016
Hardness	78.2	39	38	39	40	40
K	0.00	3.176	3.26	3.323	3.306	3.347
Mg		2.269	2.238	2.260	2.188	2.276
Mn	0.0073	0.004	0.002	0.004	0.002	0.002
Na		23.722	25.47	25.3 17	25.652	25.041
NO_3	0.05	0.58	0.05	0.46	0.07	0.44
pH	8.46	8.55	8.1	8.54	7.96	7.75
SO_4	1.13	0.00	0.31	0.00	0.35	0.54
Zn	0.0042	0.121	0.006	0.006	0.002	0.004

Table B.4. Well Water Quality Parameters Measured at Prosscr

Parameter	2/12/92	2/28/92	3/13/92	3/1 9 2	4/2/92
Al	0.086	0.076	0.075	0.071	0.074
Alkalinity	290	235	240	232	247
Ca	60.528	65.070	63.672	65.994	66.395
Cl	0.32	14.03	13.79	13.74	12.83
Cr	0.005	<0.0035	co.0035	co.0035	0.006
Cu	<0.0018	<0.0020	0.004	<0.0020	<0.0013
Fe	0.007	co.0057	<0.0057	co.0057	0.006
Hardness	265	255	266	255	271
K	3.825	4.282	4.27 1	4.297	4.147
Mg	15.381	15.833	16.295	15.832	16.542
Mn	0.002	0.003	0.003	0.003	0.002
Na	2 1.056	22.946	22.262	22.963	22.766
NO_3	26.66	19.11	18.89	17.68	0.30
PH	8.2	8.4	8.46	8.48	8.24
SO_4	co.07	40.54	41.64	42.18	42.83
Zn	0.005	0.004	0.007	0.004	0.002

Table B.S. Surface Water Quality Paramcters Measured at Prosser

Parameter	4/19/91	5/10/91	5/31/91	6/21/91
Al	0.0079	0.0339	0.0454	
Alkalinity	45	71	92	-
cl	2.497	3.12	nd	4.09
Cr	<0.0025	<0.0025	<0.0027	
Cu	<0.0013	<0.0015	<0.0016	
DO (mg/L)	12.5	--	7.9	
F	0.07	0.08	nd	0.14
Fe	0.0086	0.0364	0.0856	
Hardness	64	82	84.2	-
Mn	0.0016	0.0158	0.0285	
NH_3	<0.007	nd	<0.007	nd
NO_2	<0.08	<0.05	<0.02	co.05
NO_3	0.201	2.34	1.2	3.96
Oxalate	<0.12	co.1 1	nd	<0.11
PH	8.4	8.37	8.68	-
PO_4	co.09	<0.12	nd	0.28
SO_4	5.27	7.9	nd	11.64
TDS	70	90	loo	
Temp (‘C)	12.8	12.9	17.4	
Zn	<0.009	0.0087	<0.0008	-

Table B.6. Surface Water Quality Parameters Mcasured at Nclson Springs and Buckskin Crcek

Parameter	4/18/91	5/10/91	5/31/91	5/10/91	5/31/91
Al	0.0384	0.0560	0.0347	0.0347	0.0277
Alkalinity	95.00	145.0	135.6	--	79.90
cl	5.506	5.450	5.650	--	5.340
Cr	<0.0023	<0.0025	<0.0027	co.0025	<0.0027
cu	<0.0012	<0.0015	<0.0016	<0.0015	<0.0016
DO (mg/L)	12.00	--	10.30	--	10.30
F	0.110	0.150	0.150		
Fe	0.057 1	0.0386	0.0259	0.0494	0.130 0.0268
Hardness	92.00	135.0	134.2		
Mn	0.0053	0.0033	0.0026	5.0044	81.40 0.003
NH_3	0.024	<0.007	nd	--	nd
NO_2	<0.08	<0.02	nd	—	nd
NO_3	--	6.86	6.510	--	6.600
Oxalate	co.12	<0.11	nd	--	nd
PH	7.70	7.70	8.69	--	8.52
PO_4	0.37	nd	nd	--	nd
SO_4	10.8	12.22	11.34	—	10.36
TDS	160	150	140	--	110
Temp (°C)	11.70	11.2	14.8		
Zn	0.0178	0.0371	0.0014	0.0400	14.80 0.0220

Table B.7. Seasonal Discharge Measurements (cfs) at the Confluence of Buckskin Creek and Nelson Springs (from USBR gage station unpublished data)

Date	1979	1980	1981	1989	1990
10-Jan	18	14	-	-	
20-Jan	17	14	-	-	
1 0-Feb	1 7	14			
20-Feb	17	14			
1 O-Mar		16	14		
20-Mar		14	14	5.1	13.5
25-Mar		14	14	6	13.5
30-Mar	12.4	13	15	6	14.4
5-Apr	14.5	16	15		14.4
10- Apr	9.5	15	15		15
15-Apr	14	15	15	5.1	15.5
20-Apr	14.5	16	15	6	16.5
25-Apr	15.3	18	15	6	16.8
30-Apr	16	18	16	6	17.1
5-May	18	18	17	6	17
1 O-May	20	18	18	5.8	17
15-May	21	18	18	5	17
20-May	23	18	18	5	17
25-May	23	18	21	5	17
30-May	23	18	20	5	17.5
5-Jun	24	18	20	5	18
10-Jun	24	18	22	5	18
15-Jun	26	18	21	6	18
20-Jun	25	19	21	7	18
25-Jun	23	19	22	8	18
30-Jun	24	18	22	8.5	18

Table B.S. Summary of Herbicide/Pesticide Analysis for Two Proposed Hatchery Sites on the Yakima River. All values in ug/L.

Location	Date	Methiocarb	Prouoxur	Methomvl	Propham	2.4-DP Picloram	(mg/L)
Nelson Springs	5-22-9 1	<0.05	co.05	<0.05	<0.05	<0.01	<0.01
	6-12-91	<0.05	co.05	40.05	nd	nd	nd
Chandler Canal	5-22-9 1	<0.05	<0.05	co.05	<0.05	co.0 1	co.03
	6-13-91	<0.05	<0.05	<0.05	co.05	nd	nd

Location	Date	2.4. 5-T	Sevin	Silvex	1-Nauthol	Dicamba	2.4-DP
Nelson Springs	5-22-9 I	<o.o 1	co.50	co.0 1	<0.5	co.0 1	<0.01
	6-12-91	nd	<0.50	nd	co.5	nd	nd
Chandler Canal	5-22-9 1	<0.01	<0.50	co.0 1	co.5	co.01	<o.o 1
	6-13-91	nd	co.50	nd	<0.5	nd	nd

Location	Date	3-Hydrx Carbofuran	Aldicarb Suloxide	Aldicarb Sulfone	Oxvamvl	Carbofuran	Aldicarb
Nelson Springs	5-22-9 1	<0.05	<0.5	<0.5	co.5	co.5	<0.5
	6-12-91	co.05	<0.5	co.5	<0.5	co.5	<0.5
Chandler Canal	5-22-9 1	co.05	co.5	<0.5	<0.5	<0.5	<0.5
	6-13-91	<0.50	<0.5	co.5	co.05	<0.5	co.5

W.5

Table B.9. Summary of Water Quality Parameters Measured by Pacific Northwest Laboratory at Chandler Canal and at the Wapato Screening Facility during 1992

Site/Date	Discharge, cfs	Temp., °C	Turbidity, NTU	pH	TDS, mg/L	Total Suspended Matter, mg/L	Settleable Matter, mL/L
Chandler							
23-Apr	1,274	15.6	12.0	8.1	128	15.5	0.20
8-May	1,216	19.0	13.5	8.0	131	16.2	0.16
22-May	919	19.0	19.0	8.0	147	21.7	0.23
3-Jun	836	21.2	17.5	8.5	168	23.8	0.15
9-Sep	905	17.3	19.8	7.3	189	19.9	0.15
24-Sep	823	17.0	20.0	6.9	191	17.9	0.12
21-Oct[a]	1,612	13.3	15.7	6.0	198	17.6	<0.10
Wapato							
23-Apr	1,340	9.6	4.9	7.9	76	6.4	0.05
8-May	1,761	13.0	9.5	7.3	57	11.4	0.13
22-May	1,960	13.5	9.2	7.8	63	13.3	0.15
3-Jun	1,854	15.0	8.9	7.2	64	11.8	0.10

(a) Sample taken downstream from Prosser Dam.

Appendix C

Biological Screening Measurements

Appendix C

Biological Screening Measurements

This appendix includes additional detail on biological measures and statistical analysis.

Table C.l. Average Condition Factors for Juvcnilc Fall Chinook Hcld in Live Boxes at Various Locations During 1991

Site	Mean Length, mm	Sx	Mean Wcight, g	Sx	Condition Factor	Sx	N
Wapato 2							
5/14/91	54.30	4.67	1.31	0.40	8.00	0.59	10
5/28/91	55.60	3.75	1.29	0.44	7.30	0.80	10
6/11/91	53.00	2.74	1.01	0.10	8.80	0.63	9
Wapato 1							
5/14/91	56.10	3.41	1.60	0.30	11.00	0.94	10
5/28/91	59.56	2.30	1.87	0.28	8.80	0.63	10
YIN Net Pens							
4/19/91	50.77	3.91	1.30	0.33	9.70	0.77	30
5/1/91	55.60	4.39	1.69	0.42	9.60	0.92	35
5/14/91	60.90	6.57	1.43	0.89	11.00	0.94	10
5/15/91	66.47	3.52	2.80	0.40	10.80	0.52	10
Cle Elum 1							
5/14/91	55.50	3.37	1.43	0.31	8.20	0.83	10
5/28/91	57.30	3.71	1.38	0.37	7.20	0.74	10
Cle Elum 2							
5/14/91	56.00	3.02	1.33	0.32	7.50	0.97	10
5/28/91	55.30	3.34	0.97	0.22	5.70	0.67	10
Oak Flats 1							
5/14/91	55.20	3.02	1.47	0.33	8.20	1.30	10
5/28/91	53.60	3.34	1.18	0.26	7.60	0.67	10
Oak Flats 2							
5/14/91	54.20	1.99	1.33	0.17	8.30	0.57	10
5/28/91	54.00	4.29	1.07	0.30	6.60	0.70	10
Nelson Springs 1							
5/14/91	55.30	4.32	1.74	0.46	10.10	0.51	10
5/28/91	58.20	4.29	2.13	0.49	10.70	0.65	10
6/11/1991	59.30	4.62	2.21	0.53	10.40	0.62	10
Nclson Springs 2							
5/14/91	58.30	3.43	1.92	0.35	9.60	0.82	10
5/28/91	60.30	3.43	2.20	0.43	9.90	0.68	10
6/11/91	59.60	4.22	2.07	0.48	9.60	0.68	10
Chandler LB							
5/14/91	52.40	3.17	1.08	0.21	7.40	0.51	10
5/28/91	54.60	3.63	1.11	0.30	6.70	0.75	10
6/11/91	56.70	1.53	1.25	0.09	6.90	0.75	3
Chandler RB							
5/14/91	52.60	3.86	1.10	0.32	7.30	1.10	10
5/28/91	55.80	2.20	1.07	0.17	6.10	0.68	10
6/11/91	54.00	0.00	1.07	0.00	6.80	0.00	1
33 1 Building							
4/23/91	56.72	3.08	1.63	0.32	8.86	1.11	25
5/16/91	55.60	4.36	1.44	0.37	8.20	0.63	20
5/28/91	57.20	1.92	1.56	0.21	8.31	0.29	5
6/18/91	61.69	3.20	2.22	0.55	9.28	1.14	85

Table C.2. Lengths, Weights, and Condition Factors for Juvenile Rainbow Trout Held in Live Boxes during 1992

Site	Mean Length, mm	Sx	Mean Weight, g	Sx	Condition Factor
Horn Rapids					
6/9/92	75.7	6.20	3.60	1.16	8.3
6/22/92	85.3	4.48	4.76	0.89	7.7
Nelson Springs					
6/11/92	95.6	7.13	8.02	2.00	9.2
6/24/92	99.0	7.28	8.48	2.08	8.7
Oak Flats					
6/11/92	92.4	4.52	6.71	1.10	8.5
Cle Elum					
6/9/92	92.2	7.36	6.91	1.65	8.8
6/22/92	94.3	6.49	6.89	1.79	8.2
PNL Hatchery					
6/15/92	97.3	5.73	9.93	1.62	10.8
6/29/92	101.1	4.32	10.34	1.67	10.0

Table C.3. 1992 Egg Incubation Study Results

Egg Tube	Location	Total Eggs	Albinos Removed	Pre-Hatch Mortality, eggs	Post-Hatch Mortality, fry	Percent Mortality	Total Mortality	n=10 Wet Wt(g)	n=10 Dry Wt(g)
Heath A	Incubator	217		18	11	13.4	29	0.82	0.13
Heath B	Incubator	153	14	0	1	0.7	1	0.72	0.11
1A	Prosser	214		4	27	14.5	31	0.83	0.13
1B	Prosser	156	23	1	3	2.6	4	0.67	0.11
2A	Cle Elum	218		1	27	12.9	28	0.72	0.12
2B	Cle Elum	172	24	1	1	1.2	2	0.70	0.11
3A	Nelson Sp.	189		2	20	11.7	22	0.81	0.13
3B	Nelson Sp.	152	20	0	1	0.7	1	0.71	0.11
4A	331 Bldg.	226		6	37	19.0	43	0.79	0.13
4B	331 Bldg.	173	26	0	2	1.2	2	0.69	0.10
5A	Oak Flats	232		0	30	12.9	30	0.77	0.13
5B	Oak Flats	174	24	1	4	2.9	5	0.69	0.11
6A	Nelson Sp.	163		2	26	17.2	28	0.82	0.13
6B	Nelson Sp.	154	30	0	4	2.6	4	0.71	0.11
7A	Oak Flats	200		1	25	13.0	26	0.83	0.14
7B	Oak Flats	139	28	0	2	1.4	2	0.64	0.10
8A	Prosser	242		2	33	14.5	35	0.81	0.13
8B	Prosscr	178	31	1	4	2.8	5	0.70	0.11
9A	Cle Elum	241		6	23	12.0	29	0.77	0.13
9B	Cle Elum	150	18	0	2	1.3	2	0.69	0.11
10A	331 Bldg.	188		6	20	13.8	26	0.81	0.13
10B	331 Bldg.	186	24	1	4	2.7	5	0.71	0.11

Table C.4. Pcrccntagc Mortality Analysis of Variance, Egg Incubation Study

Main Plots	DF	SS	MS	F
Water	4	0.00130320	0.00032580	0.739278421
Blocks	1	0.00001445	0.00001445	0.032788745
Main Plot Error	4	0.00176280	0.00044070	
Sub Plots:				
Fish	1	0.07454205	0.07454205	242.610414972
Fish X Water	4	0.00085420	0.0002 1355	0.6950366 15
Sub-Plot Error	5	0.00153625	0.00030725	

Ho: There is no effect from water on fish mortality
Ha: There is an effect from water on fish mortality

Water F= .739278421 p>.50

There is no statistically significant effect on percent total variance of fish mortality resulting from the five water types.

Table C.5. Fish Wct-Wcight Analysis of Variance, Egg Incubation Study

Main Plots	DF	s s	MS	F
Water	4	0.004630	0.0011575	17.148
Blocks	1	0.000605	0.0006050	8.963
Main Plot Error	4	0.000270	0.0000675	
Sub Plots:				
Fish	1	0.055125	0.055 1250	60.246
Fish X Water	4	0.004850	0.0012125	1.325
Sub-Plot Error	5	0.004575	0.0009150	

Ho: There is no effect on growth due to the water
Ha: There is an effect on growth due to the water

Water F= 17.148 .005<p<.01

There is no statistically significant effect on percent total variance of fish growth as a function of wet weight resulting from the five water types.

Table C.6. Fish Dry Weight Analysis of Variancc, Egg Incubation Study

Main Plots	DF	s s	MS
Water	4	0.00003	0.0000075
Blocks	1	0.00002	0.0000200
Main Plot Error	4	0.00003	0.0000075
Sub Plots:			
Fish Brood	1	0.00242	0.0024200
Fish X Water	4	0.00013	0.0000325
Sub Plot Error	5	0.00015	0.0000300

Ho: There is no effect on growth due to the water
Ha: There is an effect on growth due to the water

Water F= 1.00 $p>.25$
Blocks F= 2.67 $.10<p<.25$
Fish Brood F= 80.67 $p<.0005$
Fish X Water F= 1.08 $p>.25$

There is no statistically significant effect on percent total variance of fish growth as a function of dry weight resulting from the five water types.